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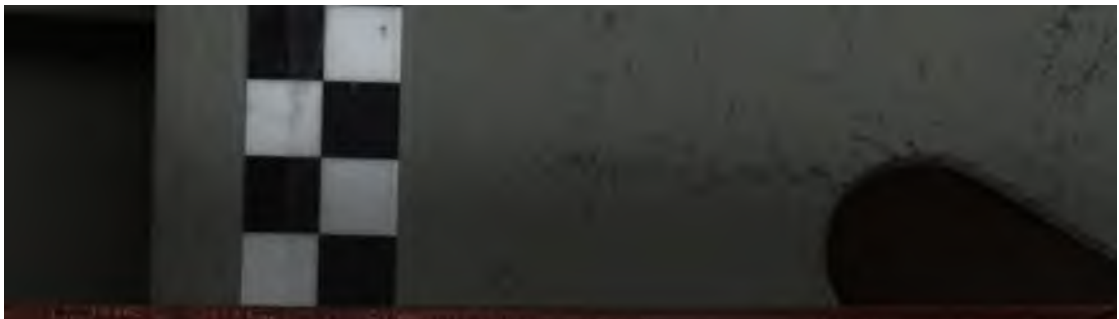

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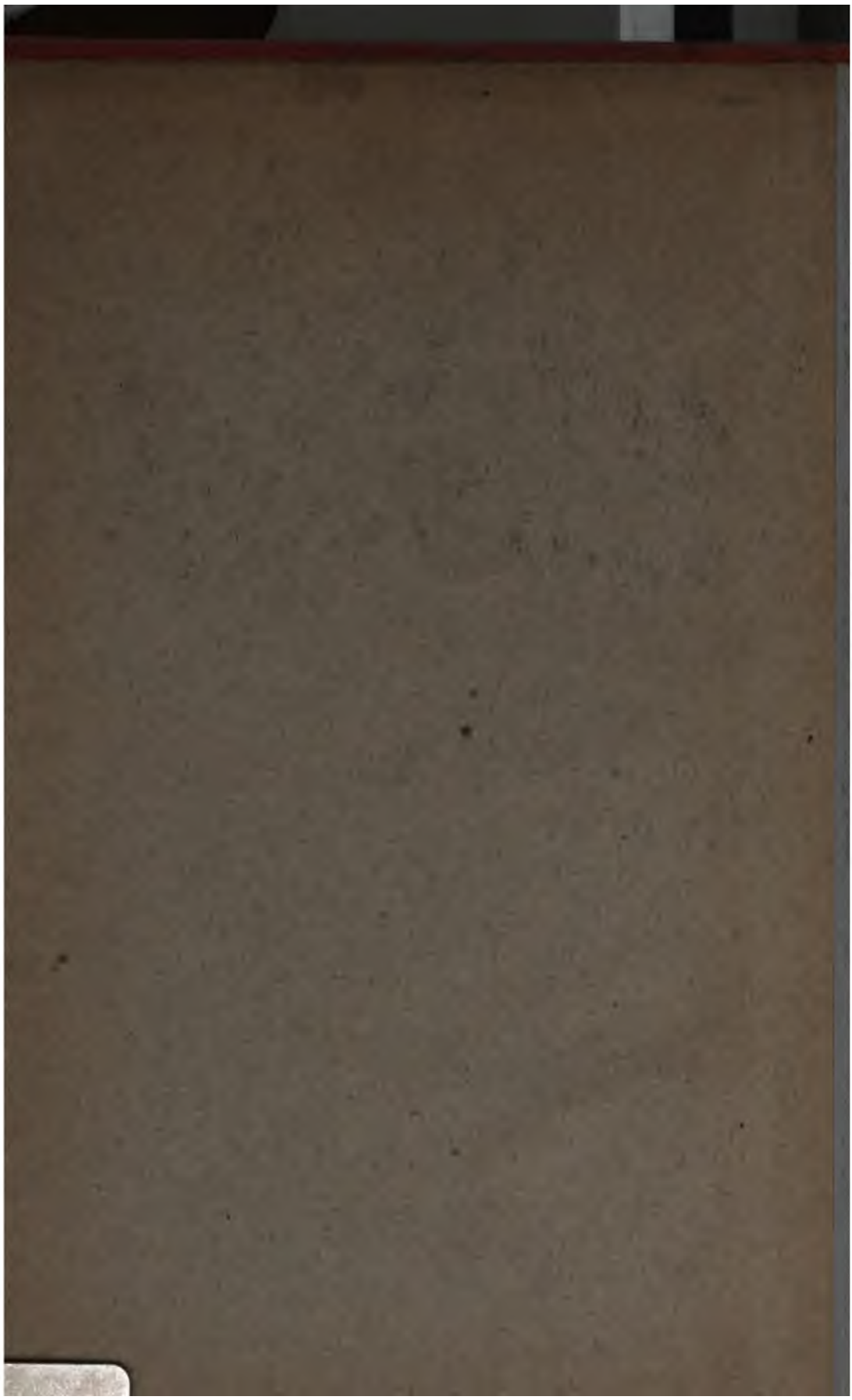

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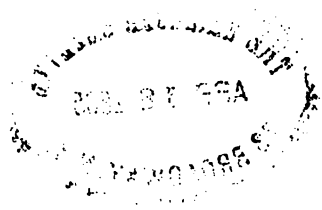

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TWENTY YEARS

WITH THE

INDICATOR.

By THOMAS PRAY, Jr., C. E., M. E.,

CONSULTING AND CONSTRUCTING ENGINEER, MEMBER OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, NEW ENGLAND COTTON MFRS.' ASSOCIATION, FELLOW OF AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, AMERICAN METROLOGICAL SOCIETY, &c., AND EDITOR OF MANUFACTURERS' GAZETTE.

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DEDICATION.

This volume is dedicated, with every sense of respect and the highest regard, to that class of men who are everywhere working to better inform themselves, to better their condition by knowledge and fidelity, and to secure greater safety in the steam power in their control, and consequently better results to their employers, and greater safety to human life everywhere—THE WORKING ENGINEERS—Marine, Locomotive or Stationary—where ever they are, in the humble hope that it may contribute to their benefit, from an extended experience of one who is practically one of them.

THE AUTHOR.

JANUARY 1st, 1885.

PREFACE.

As announced in Vol. I, this book, Vol. II, is launched, not as a literary effort or a scientific essay, but rather as a practical hand-book or text-book for the working engineer, the steam user or any who may be learning something as to the construction of engines and what constitutes the economy of an engine, what use is made of the steam after being produced by the boiler, and whether this use is good, bad or indifferent. The book has not a single mathematical formula, algebra and the higher mathematics having been entirely left out; not because the engineers could not understand them, for many of them are capable of understanding the higher mathematics, as we know, and very many make regular use of formulæ in their calculations for the sake of brevity. We have ourselves had no difficulty in expressing anything in few words without resort to formulæ; and as so many of our engineers have graduated from the fire room, and then taken positions in the engine room, or in charge of both, who have had no chance at even common-school education, we have preferred to put everything in the plainest wording, so that all might thoroughly comprehend and avoid any confusion or misunderstanding. So much for the general character of the work.

This work has been compiled from one of the most extensive practices any man was ever engaged in, at a time, too, when the author has been not only busy but a very busy man. Much of the work has been done "atween times," or when, for his own comfort, he might have been resting, and all the time during the progress of the work, which has been slow, and interrupted twice for several months, he has been busy with a large consultation practice, with the cares of a paper, and other matters, so that Vol. II has been delayed many months longer than was expected.

The subject matter of Vol. II is very largely new, only a few articles having been reproduced from the columns of the *Manufacturers' Gazette*, and in every case these reproductions have been made use of from radical points either of misuse, misconstruction, or some other peculiarities which, while all too frequent, we are not always able to lay our hands upon for ready reference. The various uses of steam cover a broad ground, from the last new ocean steamship to the 15 horse-power high-speed motor for electricity. All through the work the author has endeavored to avoid any personal reference, or to revive any criticisms other than so far as principles of mechanism, or a wasteful use of steam were concerned. Trials of engines have been for the information of the reader; trials of indicators have been to obtain absolute information for our own use, and in these cases all have been judged by the inflexible standard of right, without regard to the assertions of the several builders, patentees, improvers or venders, meaning to place on

record only those facts which were of importance in the use of this much-abused, much-misunderstood, and yet so simple and accurate an instrument as the steam-engine indicator. A large majority of the diagrams in this volume have been taken by the author's instruments and hands. It has been the aim to avoid repetition and to introduce, as much as was possible, all the conditions of adjustment, whether right or wrong, of construction or of fancy that might possibly arise upon any engines, anywhere, in any kind of service, so that the book might become more valuable to those who were far away from the builders of engines, and to make it all the more valuable to them as affording a way out of any trouble into which they might be thrown.

The extremely extended use of the steam-engine indicator within the last four or five years, has called for some book from a practical man, which should not in any case toady to the indicator builders, except to apply their instrument when it was reliable, and would record in such a manner that the diagrams were of some practical value to the men who are not thoroughly up in a wide practice. It has also been the aim of the author to be all the more guarded in offering instruction which should be of benefit to the only men for whom we are writing in general, viz., the party who owns the engine and the working engineer in charge of it, so that these two men should be entirely free from the assumption so frequently imposed upon them by ignorant and impractical men who assume the rôle of experts, never having run an engine a day in their lives.

Every diagram which is presented is engraved as nearly as it is possible with all the variations which the original contained, in other words, our aim has been not to discriminate in favor of or against any engine builder's work, but to produce actual fac-similes in size, in good or bad points, precisely as the originals were when taken from the engine. The full intention expressed with reference to the second volume has not been realized. The only point, however, is that treating upon the errors of different motions, which is in itself an exceedingly wide range of subjects, and requires a great deal of preparation as well as careful experiment. The results of incorrect motions are shown in several instances, and how to obtain correct diagrams is also in several instances carefully explained.

As referred to in the first volume, it is not improbable that the third volume will follow the second, during the latter part of 1885, in which a careful analysis of motions, the result of errors in motion, and any new features with reference to indicators, or possibly with reference to errors in the different indicators will also be fully illustrated. Much of this work has now been done. Careful study of these motions has been made, experiments are completed, but Vol. II has grown so rapidly, by including in it some of the largest marine powers, that before we would have wished it, our printer has said that we have already exceeded the limit, and the book is, therefore, somewhat larger than at first promised.

The aim in Vol. II has been to meet the latest practice in such a way that the working engineer should receive from it practical instruction, and if that end is answered, then the real object of the book is consummated.

Vol. III will undoubtedly follow before the New Year, 1886, and will illustrate different reducing motions, and methods of giving motion to the Indicator.

The labor embodied in a volume of this kind, and especially of Vol. II, cannot be estimated by any one, except its author. It has cost thousands of miles of travel, any amount of personal or physical inconvenience, in order to obta the information which is set forth, and the book, as presented, shows the latest practice in American high-pressure, high-pressure condensing and compound of the latest steamers launched for ocean service, as well as the steam-jacketed high-pressure engines.

The tables in the book have been so arranged for reference as to embody some new principles, and the table of areas in Vol. I having been found faulty, that in Vol. II has been largely computed, and any errors which were found were corrected before its being issued.

With the wish that the book may answer the purpose of a ready and reliable reference to the steam-power owner, or others interested, especially those men in charge, we send it on its way, realizing fully that it contains some faults, and without doubt many omissions, but we hope also that it contains much which is valuable, and that the favor with which Vol. I was received may be extended to Vol. II, and it is a curious fact, up to the time of this writing, that many employers have ordered Vol. II for their engineers, while in the case of Vol. I, the engineers ordered it for themselves. Evidently the employers have found that the efforts of the engineer towards self-education and a promotion, were for their interest, and we welcome this as a sign of encouragement, especially to the stationary engineers, to continue to improve themselves, which, we know they are doing, in many instances when they can ill-afford the expense. "Knowledge is power," and a stationary engineer can control his power with knowledge, to his own benefit, far better than by lack of knowledge, as so many have already found. The author will be thankful to any of the readers of this work, who will point out any error or who will suggest important points of practical use to be covered in Vol. III.

THOMAS PRAY, JR.

NEW YORK, January 1, 1885.

Since Vol. II has been in preparation, the author has received legal control of Vol. I, so that he can now furnish both volumes complete. He now retains absolute control of both books and all rights connected with them.

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TWENTY YEARS WITH THE INDICATOR.

VOLUME II.

INTRODUCTION.

THE steam engine indicator has been an appendage to the steam engine that has been entirely too little understood by the majority of men who follow the profession of steam engineering. Indeed, it has not been many years since the indicator was considered as an especial profession, belonging to a class of men who had styled themselves experts. In many cases our personal contact with these men has persuaded us that they were not only entirely devoid of any cultivation with reference to the application of the indicator, but that they were decidedly deficient in their actual knowledge of steam; while on the other hand we have occasionally come in contact with men who were in every way qualified to give honest judgment as to what they found, what they saw, and to indicate, correct, adjust and advise without any sort of reference to their pocket interest, either direct or remote. Many of these men persuaded themselves that the working engineer was only a man to shovel coal or put on the grease, oil or slush, as the case might be, and that the expert should be called in whenever anything existed that was not entirely right or up to the mark. Without wishing to criticize any, we may premise that our own efforts, dating back to 1866, have been in the direction of instructing the working engineer to the greatest possible extent and without any reserve. The attempts of some of these men to ape the experts have been amusing, but the very large majority of them have accepted the indicator as an attachment to the engine, without any of the mystery, the secrecy, or other generally supposed requirements of its adoption.

The first steam engine indicator of our own acquaintance gave a diagram which was crude in outline, only an approximation in its indications, and nothing from which we could adjust the valves or tell accurately what their condition or relation was to the stroke of the piston; and it was only when the Richards indicator (invented and perfected by our old friend, Mr. Charles B. Richards, for many years connected with Colt's Armory at Hartford, Conn.; later with the Southwark Foundry, builders of the Porter-Allen engine, in Philadelphia, and now occupying a position to which he will do credit and for which he is particularly fitted—Professor of Dynamics at Yale

College, New Haven) came into our hands, that we commenced, in the latter part of 1865, to adjust the valves of steam engines by the use of the indicator. If we had only been as careful then in keeping our memoranda as we are to-day, we could produce some facts with reference to some of the best steam engine builders in the country that would open the eyes of our readers wide with astonishment. In fact, it is a matter that is known to some people still living that we had a long, almost hand-to-hand fight. The indicator was denounced, and the man who had the presumption to attempt to get away from the old prick-punch marks and cold chisel dents on main shaft, eccentrics, straps, valves and connections, was denounced as strongly as the English language was capable of. In fact, invectives were freely used; but all that has passed away and much credit is due to Mr. Charles B. Richards for his having studied the defects of the old indicator, and by the use of the Richards indicator eliminated many of these defects of the steam engine builders, until finally the very men, who in 1865 were extremely vindictive because their old ways of working had been declared incorrect, are now the men who make free use of the indicator and who advocate it and advise it.

This change has been brought about within the twenty years covered by our own practice, terminating with the issue of this Volume II. But the indicator is now of use for more purposes than one. In 1880 we commenced a series of articles in a paper then edited by us, which shortly after grew into a large circulation, and which has done much to awaken working engineers to the fact that by extending their knowledge they could make themselves more valuable and could produce higher economy for their employers. These men, many of them, have not been slow to avail themselves of this knowledge, and in very many cases they have been personally benefited by being promoted to better positions, and there are, no doubt, many others who will be rewarded in the same way; but it is a work of time. Employers, on the other hand, have been slow, in some cases, to recognize the value of the indicator and its application, and particularly the fact that the engineer who was familiar with it, was worth more money to him or them than one who was ignorant of it. Like all other innovations on ancient practice, the working engineer must be patient and must produce the results, and then no man or class of men are quicker than employers to find the benefit of the change accruing from the proper application of the indicator; then the men who can handle it with best purpose can certainly receive all that belongs to them. But during the years past employers have a great many times been seriously misled by men who adopted the word "expert" as a prefix or suffix, and who are really incompetent, and they have paid dearly for this experience, so that really the indicator and its advocates must be prepared to outlive this reputation, which is no fault of the indicator, but rather of a class of men who live upon the credence of others. But taking it all in all, the use of the indicator has vastly extended within the last four or five years.

Following up the improvements which have been made in the steam engine indicator since the author's first connection with it (and during which time he has owned almost every indicator which has been manufactured, to

any extent at least, and some which never should have been manufactured and are not now), and finally found the instrument which for all purposes has given the most reliable results, including all that is expected of an indicator, and that is, the Thompson Improved Indicator, which is the only one illustrated in this volume, and which the author uses exclusively in his own practice on trials for power, on tests for the position of the valves, for the correctness of working steam and for all purposes wherever he is professionally called to attend to adjustment, correction, economy, or power tests; and in connection with this indicator he has used everything which has been found in the market, ancient and modern, up to the issuing of this book, making trials of different speeds, under different conditions, with different pressures, and with different positions of valves, and the trial has in every case re-asserted the correctness of his adoption of the Thompson Improved, and in some cases where very serious errors were found in either one or the other essential requirement or relation of valve, valve action, working of steam, or large variation in the amount of power, under identically the same circumstances. The author desires to state here that he has no connection with any indicator attachment, engine or steam appliance, no interest financially, direct or remote; and wherever comparisons are used they are used as matters of fact for the information of the reader and with the intention that such information shall be reliable, our sole interest being to make this book more valuable than any that has preceded it.

The various defects which are found in the old indicators have gradually been removed; some of them have been faults of mechanism, others of mechanical construction, while others have led to a change in mechanism and construction, and in some cases in the proportion of parts and to a decided change in the mechanism adopted to produce the required result. The lessons which follow this are very largely from our own practice. Some curious examples are shown, and in every case diagrams are engraved precisely as they were taken, full size, and can form the basis of comparison or can be figured from, without any reduction of proportion or percentages. It is proposed to introduce everything up to the most recent practice, particularly that of some steamships, the diagrams of which have never been printed before. Many of the matters introduced are original, particularly that of demonstrating the cut-off from the actual pressure of steam from some point on the expansion line. Some of the methods of working out diagrams we have never seen in print before, and some of the oldest engineers and best scientific men in the country have carefully gone through the demonstrations and pronounced them mathematically correct. All these demonstrations are put in plain language, without mathematical or algebraic formula, so that everyone can fully understand and work from them without reference to any of the works upon higher mathematics. Volume II. is intended to cover the whole ground, and there is no reference from Volume II. to its predecessor, and no need of reference from one to the other for any purpose of computation. Volume II. will be found to contain a far broader scope than Volume I., and it is intended to be a companion to the working engineer, to answer

his questions at all times, and to answer them in such a way that whatever may be the situation or position, he can at once adapt himself and his indicator to the case, with a certainty of correct results.

THE THOMPSON INDICATOR.—HOW TO ATTACH IT, AND WHAT TO USE.

Figs. A and B represent respectively, A an outside view and B a section. In Fig. A the parallel motion is shown, which is now made of drop-forged, compressed steel. The paper barrel is very light, and when taking off the paper barrel, there will be found inside a milled-head, above which is a thumb-screw, shown in Fig. B. The spring of the Improved Thompson is coiled, in Fig. B, into the section upon which the end of the pencil lever touches; a sleeve runs down over the spindle, upon which is a hook, and that hook engages with the inner coil of the spring. By loosening the thumb-screw shown in the sectional view B, and grasping firmly the milled-head cover, after the paper barrel has been removed, we can get any amount of tension required, changing the tension according to the speed of the engine we propose to indicate. In section B, the spring is shown, the inside of the piston barrel, with an universal joint which engages with the lever at the top and below the piston of the instrument, the coils of the spring and connection with the steam cylinder—all precisely as they are found in the instrument. If we refer again to Fig. A, there are one or two things that need to be noticed. The first is, that the parallel motion of this instrument, while sufficiently strong to withstand all necessary force as employed, must be treated with care; sometimes the springing of either one of these parts will make radical errors in the diagrams, and they must always be carefully lubricated. When applying the pencil to the paper, we do not use the little bone handle shown in both A and B, as connected with the shank which holds the stand of the parallel motion, which brings up against the stop shown between the cylinder of the indicator and the paper barrel in both Figures. A little care right here will save a great deal of trouble, inaccuracy and uncertainty. The end of the pencil lever is split, forming a shank which springs down upon the

FIG. A.

FIG. B.

lead; after the lead (leads are furnished already made) is pushed into this spring shank and through it a little distance, having been carefully sharpened, then adjust this bone handle by means of the screw and the stop, so that the end of the pencil shall not strike against the paper; but when we wish to take a diagram, having put the paper on the paper cylinder, turn on steam, then with the thumb and forefinger grasp this bone handle firmly, hold it against the stop, screw it until you feel the action of the pencil on the paper, screw it up again so that the pencil leaves the paper, and if you do it delicately, you will get the finest possible diagram without any danger of injuring or cramping the instrument. Another thing which should always be done: get the diagram as nearly as possible in the center of the paper and lead off the cord from the pulleys shown, as nearly level and at right angles as possible. Don't turn them around. A great deal of distortion comes from not paying attention to the hints embodied in the previous clause; sometimes parties who cannot afford to be delicate in their manipulation of the indicator, bend the lever by jamming the lead against the paper and springing it perhaps an eighth of an inch or more. That is sure to distort some of the lines and if the pencil lever or the radial bar is sprung, then the instrument must go back for careful overhauling and repair. The radial bar and lever, although made of drop-forged steel, are very small, and while they are strong, they will not do with rough usage, and yet they will withstand an amount of abuse that one might wonder at, after having examined them.

HOW AND WHERE TO ATTACH THE INDICATOR.

There is always a clearance in any engine we have ever yet seen. This is a space between the piston, when it is at the extreme range of stroke, and the cylinder head; this is variously estimated and in different engines varies materially in proportion of percentage to the whole volume of the cylinder. Wherever the indicator is attached there must be a clear way into the clearance, so that the piston shall not shut it off, even partially, when at the extent of its stroke. The usual connection is a half-inch gas pipe or steam pipe, and if this is carried out, it is quite large enough; whenever the engine is indicated, make sure, among other things, at the very outset by "turning her over" that no part of the piston travels over the connection into the clearance; if so, one of two things must be done, either drill another hole—and this is not always practicable—or take a chisel with point so that you can break off the inside, and give fully the area of a half-inch pipe without any possibility of obstruction or reduction. Always endeavor when tapping an engine to tap it so as to use the pantograph, remembering that the pantograph can be used vertically, so as to make your connections on the top of the cylinder sometimes, or horizontally so as to make them on the side. It is best to make these connections between the ports rather than opposite them, but sometimes there is no choice. Whenever these openings are made, take particular care that the inside end is clear, either with the chisel or rimmer, else you have a factor of uncertainty. It is a frequent practice with

many builders of the very late years, to furnish what is called a side-pipe and three-way cock with each engine. The whole thing is to be condemned, unless an approximation is wanted for the load, for the position of the valves, etc., and if our readers will turn to Lessons LVI, and LVII, Figs. 116 and 117, they will have a chance to see the position of the valves as shown by the three-way cock and side-pipe in one case, and the short connections in the other case, nothing having been moved, so far as the valves, eccentrics, etc., were concerned. On marine engines it is very fashionable (for we know no other reason for it) to take an inch and a quarter, or inch and a half pipe, lead it from the clearance at either end to the most convenient part of the cylinder, back of the side-pipes, and there put in the three-way cock. We have seen and used this upon condensing engines with 12 and 14 feet stroke, and in one case where the steam line figured $3\frac{3}{8}$ inches of the length, by the proportion of stroke on the diagram, the engineer had the curiosity as well as good sense to strip his side-pipe; two days afterwards we applied the indicator with short connections showing that the valves were open at the very commencement of the stroke and the steam line did not vary one-half of one inch when the short or proper connection was made, yet in traveling several feet it showed late, for the paper barrel started when the piston started, but the steam traveled from the clearance through the various angles and ports of the cock into the indicator with whatever little condensation took place on the way, so that the motion was distorted $3\frac{3}{8}$ inches from the truth; this makes a difference in the pressure of steam as well, so that it may be laid down as a rule, to avoid three-way connections if the real position of the valves is of any consequence, or if the actual condition of the valves is to be learned from the diagrams. Several instances of side-pipes are shown in this volume, some of these would be very dangerous if the valves were adjusted to bring the steam lines up at right angles to the atmospheric line and still use the side-pipe. It would be apt to result in something quite similar in effect to that shown in Lesson LXIX, Fig. 135.

It is sometimes impossible to use the short connection, but wherever it can be done, it is decidedly better to do it, if accuracy is any sort of a condition towards which you are aiming for results. Avoid elbows and valves in feed-pipes and exhaust-pipes as much as possible, always remembering one of the fundamental laws of all engineering, viz.: that the shortest possible distance from any given point to another is a straight line, so remember that in handling steam the utmost economy attainable wherever steam is conveyed through pipes, is invariably accomplished by taking the steam as direct as possible and avoiding every impediment or obstruction, such as is offered by globe valves, reducing valves, throttle-valves, elbows, crosses, T's, or other angles, through which steam must pass in order to reach the piston head. Anything which interrupts the flow of steam causes friction, loss of pressure; and in every case where the pressure of steam is reduced, its volume is increased and it takes the first step towards the conversion from steam into water again.

A POINT AS TO HOW TO MAKE THE LEAD DO GOOD WORK.

It is much better to sharpen the lead before being put into the spring shank in the end of the lever, by means either of a scythe-stone or dry oil-stone, or if nothing better is at hand take a fine file. A point which is rubbed up in this way, and made smooth and clean, will last much longer, make a cleaner mark and be much better than one which is whittled or coarsely done. The best way is always the easiest, the surest and the cheapest, all things taken into account. There is no necessity for running over a large number of times. This much for the manipulation of the instrument.

Having attached the indicator to the side pipes, which must in all cases be blown out thoroughly and completely before applying the indicator, be careful not to employ joints with red lead or white lead or any other material which can possibly interfere with the action of the piston; then adjust the indicator to the top of the cocks, screw down the variable screw, having first put the indicator as nearly in line with the motion as is possible, make sure that all is fast and then let the steam on to the instrument gently, warm it up, allow all the water to get out so far as possible. While the instrument is working put a drop or two of porpoise oil on to the top of the piston as it comes through the cover of the case; repeat this occasionally. Now, try the motion with the pantograph, pendulum or whatever else may be used, and carefully adjust it for the stop. The paper cylinder must not, on any account, touch either end of the travel against the stop, even so slightly as not to be noticeable, for it will distort some line of the diagram as sure as it does. Having balanced the instrument, as we term it, you are now ready to go ahead. In taking a diagram, don't work with dirty hands; you are sure to dirty the instrument, and the diagrams look as though they had been in the hands of a careless man. Putting the paper about the cylinder is a little knack in itself. The paper should go down square, fit as close as a glove, and be just as clean as though it had never been touched; a little practice is required. Having accomplished all this, let the steam in; don't take the diagram until after the instrument is heated. Take the diagram first as per previous directions, shut off the steam, being careful not to allow any steam to blow through the three-way cock, and the moment this is closed tightly then take the atmospheric line while all parts of the instrument are warm. If the atmospheric line is taken before the instrument is thoroughly warmed up, it will be incorrect; if it is taken after contraction has taken place by cooling off, even some time after the diagram, it will then be incorrect. Take the diagram first, the atmospheric line afterwards; then, having noted the steam pressure, knowing the dimensions of the engine in diameter and stroke, and number of strokes or revolutions, put all this data carefully upon the proper place in the card; be sure and add to it the scale and any memoranda which are necessary, and you will have progressed systematically; and if you have followed the directions given for handling the pencil, you will have produced a beautifully-drawn diagram, which will give you the correct working of the

steam, the position of everything and its relation to the economical, or otherwise, handling of the steam.

THE STEAM WHICH A SPRING WILL TAKE.

The American Steam Gauge Company give their rule as: Multiply the scale of the spring by $2\frac{1}{2}$ and subtract 15; the result will be pounds of steam pressure from the vacuum line that the spring will take accurately; as, for instance, $30 \times 2\frac{1}{2} = 75 - 15 = 60$. We think this might be changed with benefit, for it is not always necessary to provide for the 15 pounds vacuum, and it is desirable always to make the indicator diagram as large as can be. For this purpose we adopted some years since the practice of having a set of washers made, which would slip on to the sleeve under the cover on top of the indicator piston cylinder, or upon the shank of the piston itself at the bottom, and these washers vary in thickness from $\frac{1}{32}$ of an inch to $\frac{1}{8}$ of an inch. By these means we can take 75 pounds of steam with a 30 spring by first blocking down the pencil lever; instead of standing, as shown in Fig. A, it will stand nearer the bottom of the paper cylinder when at rest. There are two things to be guarded against: never under any circumstances undertake to indicate a pressure of steam which shall be beyond the capacity of the spring; for in the one case you will bring up solid, and in the other case, at the top, you will throw the pencil lever out of a parallel line by passing beyond its capacity, and get something which may appear to you like Fig. 135 in this volume. It will distort the lines and not do the instrument any good.

The best oil that we can obtain is pure porpoise jaw oil; ordinary mineral, animal or vegetable oils are affected more or less, and the porpoise oil, which is worth a good many dollars a quart, only requires a very small amount if you use it carefully; this should be used on all parts of the indicator.

Before we leave the subject of springs, it may be proper to state that the softest spring which can be used, and keep within the limits of its capacity, is the spring in every instance that you should use. The practice is becoming quite common among parties in this country of using 50 and 60 springs, and in other places of using a small diagram, the smaller the better. In every case keep clear of this kind of practice. The larger the diagram, the more the faults of the instrument are shown, if there are any, and the more the faults of the engine builder, if he has been careless in his construction. The only case where we advocate the small diagram is with engines running above 300 or 350 revolutions. This will be referred to later. The smaller the diagram, the less real reliance is to be placed upon it, and the cause of this will be found in some of the lessons on high speed, where different diagrams are referred to, and the real reason why the larger scales should be always used will be found with a little reasoning.

CHANGING THE SPRING.

It is frequently necessary while working upon an engine, for some reason or other to change the spring with varying pressure, speed, or some other requirement. There is no reason why this cannot be done in about one minute, providing you have the spring where it is wanted, and understand your work and are careful about it, and there is no instrument we have ever seen that begins to compare with the Thompson for accessibility. Having decided, you must change the spring, commence with the connection of the top of the piston with the pencil lever, taking out the little milled-head screw, then release the pencil bar from the piston, taking notice that the ears on the piston connection have a screw-thread in one and a clear hole in the other side; having separated these, then unscrew the cover to the piston casing, lift the whole thing off, piston, spring, cover, pencil lever, etc. Be careful never to drop the piston upon a gritty floor, rather take it in your handkerchief o some other clean cloth; now unscrew the piston from the under side of the cover, the spring from the lower end of the piston, put on the other spring, screw it on to the shank on the upper side of the piston, put it through the casing, screw the shank of the cover into the top of the spring; now put the top of the connecting rod so that the pencil lever will easily drop between the two ears, adjust the screw which passes through one ear, then through the pencil bar, and screw into the other ear on the top of the connection rod; screw the cover into the casing, after having put a drop of oil on the piston, and see that it works easily back into the casing, and that the piston drops easily into the cylinder and the cover goes down into the casing all easy together, and that the pencil lever, parallel bar and radial lever are all easy and none of them are sprung, having previously taken care that the connections are all blown out, so that no dirt can be blown into the indicator from any of the connections. This can all be done in less time than it has been written in. You are now ready to go ahead.

GENERAL HINTS.

Sometimes, in taking the indicator off from the steam connection, it may receive a jar in such a way that the stand which connects the piston barrel and the paper barrel together may be sprung. We have sometimes found this to be done. There is no necessity for it; it should never occur. If it occurs, and you are out of reach of help, you may take the thing in your own hands; but never take a diagram unless your pencil bar describes an absolute right angle line to the atmospheric, and then it is a good plan when this occurs to send it back to the shop to be put into the jig and examined. It may have a crosswise spring, and except a diagram is accurate it is valueless.

The Thompson Improved Indicator succeeds the Richards' Indicator, which has worked a revolution in engine building. When speed and other matters of importance came up, Mr. J. W. Thompson patented the parallel

motion, not shown, for it has now practically been discarded, and has been displaced by the Improved Thompson, shown in Fig. A. This instrument is manufactured solely in the United States by the American Steam Gauge Company, Boston.

We call the attention of the reader to Fig. C, which is not all that we wish it were. It is the Thompson Improved Indicator, with the detent motion attached, by which the paper cylinder may be caught and held while the paper is changed without unhooking the cord. This is extremely simple; it does not interfere with any other part of the instrument. It is perfectly satisfactory in its working, and for people who are not accustomed to high speeds or to close quarters, it is a very great advantage. For our own individual use we would not have it, for we prefer to feel of the attachment to the motion every time we hook and unhook, and do not care what the speed is as long as it is below 700; but there are so many men who only take diagrams occasionally, and are not up in the little knacks of an extensive practice, that this detent motion will be a very great accommodation to them, and without doubt will make their indicators work better and last longer. It is so arranged as to be completely under the control of the operator, and it can be instantly disconnected if desired. The change is accomplished by simply sliding out or in the little knob seen on the back of the steam chest (shown in Fig. C), which engages with a tooth in the paper cylinder barrel wheel seen at the right.

FIG. C.

GIVING THE MOTION.

Leaving Figs. A and C, a peculiar device is seen, for the lack of which there has been much trouble in times past. Fig. D shows an improved method of taking the motion off the paper barrel. A represents the wheel, which is also shown in dotted lines in a different position; B represents a stand holding the wheel over which the cord passes; and the end of the stand is a sleeve running into the solid stand shown, the whole thing being bored through; and the flat

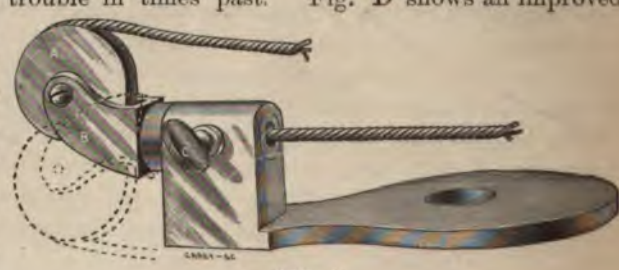


FIG. D.

part shown at the right is secured against the bottom of the stand by means of a thumb-nut at the lower end of A, B, C. The sleeve which extends into this stand has in its center a groove into which the flat-headed thumb-screw, C, enters, holding it in any position, to the right or the left, up or down, giving it the full swing of the whole circle, and in this way the motion can be taken from any point, at almost any angle that it is possible in the whole 360°, either horizontally or vertically. It is one of the improvements made by the Steam Gauge Company within the last two years, and is the subject of separate patents. Wherever the old plan of wheels is in use on the old Thompson or the Improved Thompson, this can be substituted if required. All instruments now made are made with the device shown in Fig. D, and this device, as simple as it is, makes it possible to use the instrument in many places where special motions had to be arranged by the old method.

We now come to the

METHOD OF ATTACHING THE INDICATOR, OR OF MAKING UP THE REDUCING MOTION.

There is probably no one device which has been used so much as the old pendulum, and there is no device which is so generally incorrect or so much misapplied. These pendulums have various faults, and the usurs of them have many vagaries. We recently saw in a large engine-room a pendulum attached to a piece of iron, leading from one girder to another in a fire-proof arched floor, and it is no exaggeration to say that the top of the pendulum chattered from an eighth to a quarter of an inch sidewise, while the strap which passed from one girder to the other jumped up and down as much more, making a most peculiar motion. The string was then taken off at an angle of 10° or 15°, brushing by the side of the steam-pipe, and was deflected from the straight line between the carrier pulley above and the indicator pulley below more than one inch. It was perfectly useless to attempt to show the party using it that he had errors multiplied by each other into an outrageous accumulation, and that his diagram was worse than worthless for any purpose whatever. The pendulum can be used. It must be firmly fixed at the top, it must be strong enough in its cross section not to spring either edge-wise or flat-wise; the bottom of the pendulum must in every case start from the actual center of motion, it must travel precisely as far one side of this center of motion as the other and not an iota farther one side than the other; in other words, it must be exact. If these simple precautions are heeded, then the pendulum becomes endurable, but in taking off the cord it must not be taken from a point near the top at an angle anywhere from 1° to 120°, down to the indicator direct on the cylinder. It must be taken at right angles to the central line of the pendulum when at rest, to a point over the indicator, and if only one instrument is to be used, the carrier pulley may be placed on a line plumb over the center of the cylinder, so that the cord leaving the pendulum shall leave it at right angles absolutely when it hangs plumb, and passing over the pulley, there is no necessity then for continuing this exactness,

for a little to the right or left of plumb in that case does not distort the motion; but if the first portion is not at right angles, then we get distortion of the worst kind. The pendulum may be inverted by the same precautions, as it is sometimes impossible to get a pantograph between the cross-head and the side of the wall; or we have, in some cases where we could not use either on account of too much distance at one end and too little at the other, laid a pendulum on its side; most men would not take pains with this and we do not therefore advise it.

Instead of the old means of attaching, Fig. E shows what is known as Bacon's Improvement, being a combination patented by our old friend F. W. Bacon, made by the American Steam Gauge Company, consisting of five pieces; the jointed links at the right are intended that the longer parts should be put under the check-nut of the oil cup to which it may be attached on the cross-head; the shorter parts turn over each other according as the longer parts may be farther apart or nearer together, until the holes match, through which the screw-thread shank, shown at the top with a hole through it, may be used for the pantograph, or the screw-thread at the bottom may pass through this hole and be used in the pendulum, as is shown in Fig. F. There are a great many ways of attaching this to different engines which will be followed up. Fig. E shows the parts in detail, Fig. F shows them attached to a pendulum, Fig. G shows the top of a post, pantograph, and the Bacon attachment connected to a vertical cross-head, although the cross-head is not shown, it simply shows the method of attachment. Fig. H shows the pantograph attached to a vertical cross-head and the pieces are attached to the shoe at the bottom by simply raising up the nut which holds the slide in, and then gripping them by screwing down upon them again. In both of these methods of attaching the pantograph, bear in mind the rule with reference to the pantograph. The post on the outside must be set at exactly right angles to the center of motion when at rest; in other words the pantograph must travel precisely as far one side as the other of the center of motion, and not as we have sometimes seen it, forming the hypothenuse of a right angled triangle, working all the distance one way. Fig. I shows another method of connection to the Corliss cross-head, to which all the same rules apply. Fig. J shows the pantograph and the Bacon attachment connected to a horizontal cross-head.

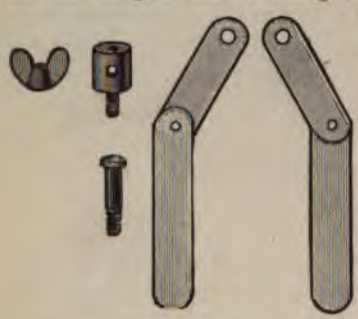


FIG. E.

FIG. F.

FIG. G.

RULE FOR THE PANTOGRAPH.

In all these attachments of the pantograph, whether horizontal or vertical (and the pantograph can be used as well vertically as horizontally, if a little care be used in attaching it, being the simplest and the most correct of all the motions known), let the pantograph be attached as shown in Fig. J, whether it be the center of the cross-head or one end of the cross-head is entirely immaterial, but let that point at which it is attached be invariably the exact center of motion. Set the out-post square with the center of motion, and in no other place or position. Now, as the stroke of the engine varies it is necessary to get more or less motion, which can be done by moving the peg-post or peg arm out or in on this line, which has been drawn squarely across with the center of motion. Let the line from the peg-post to the indicator be at a right angle to the center of motion, or in other words, let the line which connects the peg-post of the pantograph with the paper drum of the instrument, be as nearly parallel with the piston rod as it is possible to get it. If these two simple rules are observed, any engineer can obtain a diagram which is mechanically, geometrically, and mathematically as correct as any other man on earth can do it. We have frequently said before different audiences, written it over and over again: the indicator diagram, the valve motion, the pantograph or the pendulum, are only and simply a combination of right angles. If everything is done exactly on the square, everything else will be exactly right, whether you are working for the position of valves, use of steam or anything else; the indicator diagram in this case with these two simple rules observed, will be a positive quantity, perfectly reliable, and if these two rules are not observed, it is as perfectly and as completely worthless as it is possible to be.

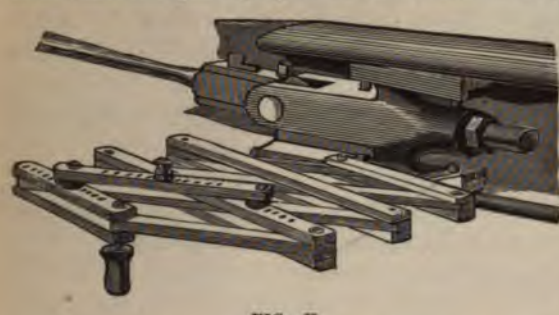


FIG. H.

Fig. K represents the pantograph more in detail, with letters of reference. This simple arrangement, like so many other things, we are indebted to George H. Corliss for. It has a great variety of names; it has been called "lazy tongs," "long legs," "pantograph;" it was originally called and we believe Mr. Corliss himself terms it his "drum motion." It consists of nothing more or less than a system of levers; these levers must be absolutely

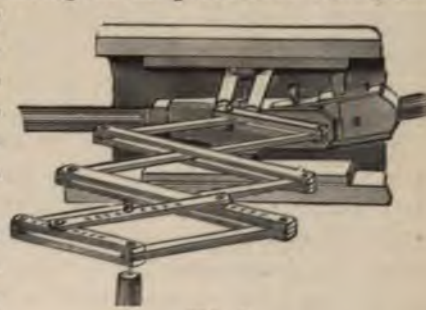


FIG. I.

of the same length, those shown at A being double and those at B being single. These are pivoted by means of hollow pivots and washers which are bushed. The hitch strip is shown at G and the stud-pin or hitch-pole F. When the pantograph is properly arranged the stud-pin F is in the line between C and D, which are the two ends of the pantograph, one being the dead end D, which is fastened to the post, while C is the live end or attached to the cross-head of the engine. The point C attaches, where Fig. E is used, to the two links connected together, so that the pin at the end, C, readily drops through them. If the links have to be used so that they stand vertically, then the little screw-head, shown in Fig. E, is attached by means of the thumb- nut and the taper end at C drops into this screw-head, turning a vertical into a horizontal bearing, the least variation in the location of the pivot-holes in the "lazy tongs" or pantograph will be met by an absolute refusal to work at all, and we have no doubt that some of our engineers or mechanics who have attempted to make a pair of "lazy tongs," have had lots of fun out of it, and nobody else been any the wiser; whether they enjoyed the fun or not, we do not know. Correctly made, the pantograph is complete, but with the slightest variation from correct, it is like the diagram from a distorted motion, absolutely incorrect and worthless.

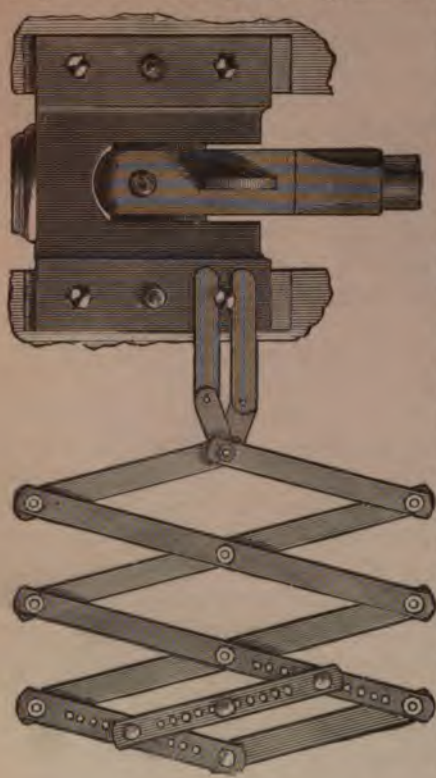


FIG. J.

In applying the pantograph, let the end C drop into any point on the cross-head to which you can attach, or any one of many ways which will readily suggest themselves to the mechanical engineer. The end D may drop into the top of the post, or we frequently build ourselves a little stand of inch boards, four inches wide, braced, and then get two or three hundred pounds of old iron or anything else which is heavy, and when

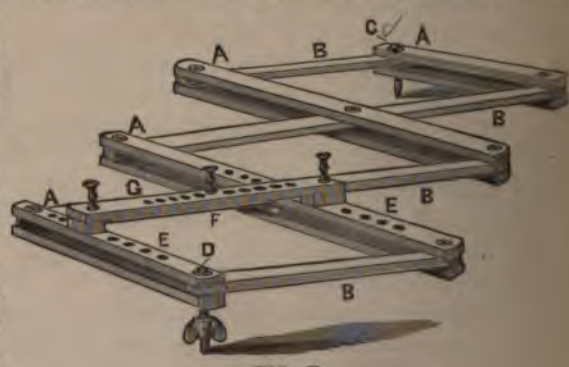


FIG. K.

we get it in line, weight it down, square it, have the points C and D exactly level so there will be no weave or strain, or cross motion which will vitiate the correctness of your diagram. The line from C to D must invariably be at right angles to the line of motion of the cross-head, and absolutely in the center of motion; then shove your post at D out or in to get more or less motion; put the stake-pin F wherever you want it, and set this peg F so that the line from that to the indicator shall be parallel to the piston or parallel to the line of motion of the cross-head. If you cannot do this, or if from any cause it is necessary to have the peg-pin, hitch-pin or stake-pin, F, further away from the cylinder than the indicator connections are, immediately set up a second little stand, and take the cord from the peg F parallel to the motion of the piston, and around the guide pulley to the indicator. Whenever the pantograph is properly put up, every point on a line from C to D is a positively true motion, parallel with the guides, varying from nothing at D to length of the stroke at C. Wherever engineers wish to use one motion for several engines there is nothing better than a piece of gas-pipe, ground off, with an attachment which may be fastened with a set-screw to slide up or down to fit different engines; to this attachment may be fastened a socket to catch the D end of the pantograph while the other catches into the cross-head. By means of a T on the top of the piece of pipe, which has a flange at the bottom for screwing to the floor, are connected two side pipes standing at a right angle to act as braces; this can be attached to any engine or flange, screwed down, the braces squared and screwed down, the piece that slides up or down put at the proper level, the pantograph hooked on and you are all ready to go ahead.

SLIDING LOOP.

There are all sorts of hooks, slips, knots, and other matters used for connection; until within the last few months we have invariably used the old-fashioned, flat, sliding loop, which is about as nearly worthless as anything can be. While doing some work for one of the lines of steamers, our attention was called to a crude idea by the chief-engineer of one of the ships which we have put into shape, and is shown at Fig. L. This is so clearly shown that no description is necessary; it is a piece of brass tube, spun over at the end, finished, holes bored through it and finished, and it is the only thing in the way of a sliding loop we have ever seen yet that was worth talking about or using. The American Steam Gauge Company make them, there is no patent on them, and any one has the right to make them. We prefer always to use a plain hook on the end of the indicator cord, which is attached to the paper barrels, having means of adjusting by use of this sliding loop from large to small or long to short, using as little cord as possible, more especially on a high-speed engine. We prefer this adjustment to anything we have ever seen, for where we are working with water steam,

FIG. L.

more or less heat, oil, or any of the other accompaniments, no cord will retain its position for any great length of time by any device we have ever used, until we adopted Fig. L, and some method of ready adjustment is necessary. We have previously referred to the adjustment of the paper barrel by means of the cord, and now having proceeded to obtain the diagram, if the directions have been followed, we are ready to commence the computation of the diagrams.

THE DIFFERENT METHODS OF COMPUTING THE INDICATOR DIAGRAM.

The indicator Diagram, having been taken, should bear on it memoranda taken with each and every diagram when it comes from the indicator, wherever the work may be performed; this data should bear upon each diagram, or each pair, the diameter of the cylinder, the length of stroke, the revolutions per minute and the scale of spring with which it is taken, for these are the most important elements and without them the diagram cannot be correctly worked. Wherever it is possible to ascertain the percentage, the clearance should also be noticed. Many engineers of late have accustomed themselves to ascertaining the clearance of their engine so as to know precisely what the amount is. It is also a good plan to carefully note the pressure of steam in the boiler by the gauge, and also to notice whether this gauge shall be located above or below the line of the cylinder, and whether there is hanging on the gauge a column of water in the siphon several feet in length, or in the vacuum gauge, how or where it is connected, for we frequently find very radical differences between the pressure in the cylinder and the pressure as shown by the gauge. All these items of data are particularly necessary, for if they are clearly expressed, we may then judge pretty well of various peculiar points which so frequently occur on the diagram, and having the data at hand, we can in every case base our judgment upon fact, and know how a certain falling off or back pressure or any peculiarities of steam or exhaust will be explained by comparison of the data with the fact.

WORKING UP THE DIAGRAM.

If the motion has been properly attached to reduce the stroke of the engine, we shall have an accurate card, and without it is accurate, it is not only valueless but a waste of time. Endeavor by all means to keep the card clean and to avoid the possibility of any mistakes. The general unit called for is the horse-power of a diagram; the unit of horse-power is 33,000 pounds lifted one foot high in one minute. For this reason we use the length of the stroke, the revolutions per minute and the mean pressure of the diagram, and then by computation, obtain the horse-power. Having our diagram before us we proceed to work it up, and the working up simply obtains the mean pressure from an irregular form. There are several ways of working up an indicator diagram; the one most generally in use, up to five years ago, was dividing the diagram into ten ordinates or lines at right angles with the atmospheric line, and at equal distances from each other, and then measuring

by the same scale with which the diagram was taken, the pounds of pressure upon each one of these ordinates, which was exerted on the piston, then dividing the aggregate by the number of amounts, giving the average or mean pressure. But this was crude, it did not take into account little differences which exist, and while not very far from correct, it was far enough to make a very considerable difference as between the correct computation and the one practiced; hence, this has been discarded for general use.

Another way, which is virtually the same thing, was to take a narrow strip of paper, perhaps one-eighth or one-quarter of an inch wide, and marking the steam pressure on the first ordinate from the end of the paper laid on the atmospheric line or line of back pressure, then put the first mark on the atmospheric line or line of back pressure of the second ordinate, and mark the top of the second ordinate by another short mark of the lead pencil; in this way we are simply adding them together. When all the ordinates have been measured (measure them in inches), multiply by the scale of the spring as 20, 30, 40, and divide by the total number of ordinates measured, and you have the mean pressure. But this has virtually the same inaccuracies as the first method of measuring.

There is still another way by which many diagrams have been measured, and that is a sort of general average; taking a piece of glass with a straight edge, it is placed below the steam line and above the lower part of the expansion line, until the two quantities apparently balance each other and a line drawn across the length of the diagram; its height found, multiply by the scale, this gives the mean pressure. But this, too, has been discarded and for the last few years the planimeter has been used, and is the only correct way to work up any diagram; the fact that it is named planimeter is another way of expressing the fact that it is for measuring plane surfaces without regard to how irregular their form may be.

Fig. M shows a modification of the Amsler Polar Planimeter, as made by the American Steam Gauge Company, Boston. Other forms of the instrument may be bought if desired. The proper use of the planimeter will reduce any irregular surface to a parallelogram or square by observing its reading carefully, measuring by means of the pointer, and then reading from the index wheel and vernier and obtaining the value as indicated by simply adding or subtracting. The point at the left is a needle point, which should simply be set into the paper on which it is used, and it is better to use a medium, rough, brown paper or blotting paper, something which is not calender finished on the surface, than to use a smoother paper. Having fastened the card, as shown in the cut, by a couple of pins or tacks, commence at any point you choose, simply making a mark with the point of a pencil; traverse the point, shown at the right, over the line of the diagram in the direction of the hands of a watch, or from right to left on the line which is

FIG. M.

shown. Having pinned the diagram down on the paper (which, by the way, should be upon a smooth board or surface), next adjust the planimeter so that the index wheel, which is graduated about its entire circumference, shall not meet with any obstacle in its course, or anything to interfere with a perfectly free motion. Now obtain the reading. There are a series of figures about the circumference of the index wheel, from one to zero, making ten lines; each one of these divisions has ten subdivisions, while the vernier, shown at the left of the index wheel, has eleven divisions in exactly the same distance that the large wheel has ten, so that wherever the index wheel stops one division on the vernier will be bound to correspond with a division on the index wheel. We will suppose we start our reading and that the figure 3 is past the zero on the vernier; we then count that 6 above 3 is a trifle below zero on the vernier. We now cross over on to the vernier and find that 3 on the vernier exactly coincides with a division on the wheel. This makes our reading 363. We now travel the index point at the right, around the diagram, until we stop at the same point from which we started. We now find that 5 has passed below zero on the vernier, and that the third line above 5 has also passed; then running up the vernier, we find that 8 stands exactly coincident with a line on the index wheel. We have our reading then 538; subtract the first reading from this, the result is 175. Now repeat the operation two or three times until you get three readings, which may be 175, 176, 174; they will vary exceedingly little if you pay careful attention to following the lines. The average of these three readings is 175, which is correct. There is no necessity, although it sometimes saves trouble with a beginner, or doubter, to place the zero on the wheel against the zero of the vernier in starting. If this precaution is considered necessary, a few trials, without commencing every time at zero, will convince any one that it is entirely unnecessary. We first read from the index wheel the figure which has passed the zero on the vernier; this we will call hundreds. Then count the lines up until you find which one has passed zero between that and the next figure; this is tens. Then follow the vernier until a line is found which precisely coincides with a line on the wheel; this is units. The instrument is exceedingly simple, and there can be no mistake whatever if care is given, for the reading is just like that of a clock or watch—may be taken at any point through the day without figuring from twelve o'clock or six o'clock. This gives you the area of the figure in square inches or in fractions of a square inch. In case you read so that zero on the wheel completes the circuit and passes zero on the vernier, you must then prefix 1 to the hightest number previously read. If in the case we have just cited we are working on hundreds, your first reading should be 175, the second 350, and so on until zero passes; you would then prefix 1, which would make it thousands instead of hundreds, and if it passes again it becomes two thousands instead of one. A little practice with the instrument will familiarize any one, and a little pains taken to familiarize yourself with the reading will shortly put you in possession of the key to it, all which is so plain that no mistake need occur. The instrument will work precisely as well backward, but unless care is taken, and you should obtain a diagram

which had a compression loop at the top and an expansion loop at the bottom, you might get a negative result which would be incorrect. So, until you are familiar with it, always work it like the hands of a watch or as shown in the cut, from right to left, following the diagram around in the same direction; there will then be no possibility of trouble. The planimeter does not make any allowance, but if the work is correctly done you have at once a correct result from the outline, and by the use of the planimeter the different areas of the diagram may be separately measured with perfect exactness, so as to ascertain the value of the vacuum apart from the steam, or the high pressure and low pressure cylinders of the compound can be very accurately measured, without any regard as to whether they are all taken on the same scale or not.

Another point which is frequently one of great interest, is to measure the difference between the power in the condenser, taking the vacuum gauge, and the result as given by the indicator in the condenser. The line can be drawn to show what would be the result in case the pressure—as shown by the vacuum gauge—was realized in the cylinder; so you may get the actual as compared with the gauge result, and in this way make comparisons showing the absolute value of any factor which is contained in the diagram.

TO ASCERTAIN THE POWER FROM THE PLANIMETER READING.

Many of the diagrams illustrated in this work have lines at the steam end, and release end, which are erected at right angles to the atmospheric line and line of vacuum. The length of the diagram, without any regard to its form, whether there be a heavy compression loop on the steam end, or an expansion loop on the other, or any imperfection in release or exhaust,—the length of the diagram is the extreme distance from the very ends, and if a little attention is paid to the way these lines are erected, there will be no necessity for any difficulty in getting at the exact area; for, wherever a compression or expansion loop is contained in the diagram, start at any certain point and follow the diagram line as the indicator made it, and the loops, which are resistance, will be taken out of the area by the instrument without any further care on the part of the manipulator.

Having accomplished the measurement of the area, we now desire to compute the power. In order to save a great many figures it is better to compute a constant for each pound of mean pressure (even if at different speeds) instead of having to do this with every diagram which is worked up. This is produced as follows: Take the area of the piston in square inches, multiply this by the number of feet traveled each minute, and divide this result by 33,000; the result will be the constant which shows how many horse-powers, or what fraction of a horse-power, is yielded by every pound of mean pressure on the diagram. Having the area of the diagram in square inches or fractions of an inch, divide the area by the length in inches or fractions of an inch (farther on in this work will be found a table of fractions

of an inch, decimally expressed, for convenient reference),—the area divided by the length of the diagram gives a result which may be a decimal or otherwise. This is to be multiplied by the scale of the spring for the mean pressure; then the mean pressure multiplied by the constant (directions for which are given above) gives us at once the horse-power, and in the simplest possible way.

If we have, for instance, a diagram measuring 450, which is equal to 4.50 square inches, and which is $2\frac{7}{16}$ inches in length, see the table and find that $\frac{7}{16}$ equals .4375 inch. Now, the area 4.50, divided by 2.4375, equals 1.846, which means that a parallelogram 1.846 inch in height would be exactly equal to the irregular figure which has been described by the indicator. If we have been working with a 30 scale we have only to multiply this 1.846 inch by the scale 30, which equals 55.380 pounds of mean pressure; multiply this by the constant or number of horse-powers which every pound of mean pressure gives, and you have then the horse-power of the diagram.

It is frequently a matter of satisfaction to the beginner, in the use of the planimeter, to have something with which to test. This can be very easily arranged by drawing a circle with a pair of pen dividers, one inch in diameter, or any other sized circle that may be desired (we mention the circle because it is more easily drawn correctly, as a general thing). Having this, measure it by the planimeter and then see if its reading agrees with the table of areas. This will always give you a test gauge.

DIFFERENT FACTORS IN THE DIAGRAM.

It is frequently necessary to ascertain the amount of back pressure in horse-power, which can be done if the atmospheric line is perfectly taken and the diagram is also correct. The amount of vacuum in comparison with the amount of steam worked, or the loss in vacuum—all of these are interesting features; while if the reader will familiarize himself with the theoretical curve, as applied to any diagram shown in the lessons further on in the work, he can then see what amount of steam, properly handled, would have done the same or more work, perhaps, than is shown by the diagram from which he is working. The planimeter is invaluable for all this. To get the percentage of the condenser work, as approximating the theoretical, erect the absolute vacuum line, and then measure the exact amount of vacuum as shown by the indicator, and it is very easy to immediately convert the actual into a percentage of the theoretical, taking the theoretical vacuum at 14.7 pounds. Comparison of realized pressure with boiler pressure is frequently an interesting matter. Erect the line of boiler pressure, from which you can carry all computation, so as to get at the actual and the theoretical. The planimeter measures these irregular forms with absolute correctness, if the operator works with care in tracing the lines, and in a fraction of the time that would be necessary by any other method.

NECESSITY OF RELIABLE DATA.

There is frequently a great deal of ambiguity about information obtained from people in charge of different engines. Wherever a man is sent to work with an indicator, there is only one correct way: Pull off the cylinder head, measure the cylinders and the volume of clearance, and make everything as near correct as possible, for very slight differences are frequently fatal to the report on the case, and carelessness is entirely inexcusable, guess-work or assumption very much more so, and we have seen old and intelligent engineers thrown out of court very abruptly, because of some radical error, even though trifling in extent, shown in their report, where they had, to save themselves a few hours' hard work, assumed that because one part was one size, the other was the other, or some other equally trifling matter which was more than vital to the case. While some more careful man had shown in details that such difference existed, and by that means had thrown doubt on the whole of the work of the careless man. Correctness in every possible way is an element of value, and a lack of care or thoroughness makes an indicator diagram absolutely worthless.

LESSON XLI.

DEMONSTRATING THE ACTUAL POINT OF CUT-OFF FROM THE STEAM USED, WITHOUT REGARD TO TERMINAL PRESSURE OR LACK OF DISTINCTNESS IN THE CUT-OFF LINE.

In our own experience, we have frequently been unable to determine the point of cut-off with sufficient accuracy or reliability, wherever the line of the diagram was not clearly defined, and this oftentimes becomes necessary in making computations, or in comparing one engine with another for efficiency. It was, therefore, after considerable investigation, that we adopted the method first published by the writer, September 15th, 1883, as a method of demonstrating the positive point at which steam is cut off, or a point on the line of initial pressure equal to cutting off steam at a particular point, even where a leak had occurred, or where steam had drifted past the steam valve after it was supposed to be closed. At that time we used the following expression: "We have, therefore, stolen a march on volume two of Twenty Years with the Indicator, by showing the mathematically correct way of demonstrating the positive point at which the steam is cut off, or a point which is equal to the cutting off of the steam at some especial or particular point whenever steam leaks or drifts in."

Since this statement was made, this method has been examined by some of the best mathematicians, and has been pronounced correct. It will be referred to in the following lessons in this volume as *the* demonstration or our demonstration. We reproduce the original diagrams, now in our possession, which were published with this first demonstration.

It has been customary in years past for builders of engines, engineers and experts to erect their comparison from the "axis of the hyperbola," or from the terminal pressure. "The axis of the hyperbola" is an indefinite, uncertain quantity, and the terminal pressure is as apt to be wrong as right, and we wish to impress upon the reader of this, that in this case we divide the problem into two different and distinct demonstrations; first, we locate the exact point of cut-off on the line of initial or realized pressure in the cylinder, from a point a little past or at the center of the expansion line of the diagram. The reason why we do this is that at or a little past the center of the expansion line, the steam has become more settled in its action, is less liable to irregular pressure, the speed of the piston is nearer constant, and the load affects least either the piston or the crank in overcoming the resistance, on the same principle that a train of cars, after in motion, gives a better idea of the actual load than when starting or stopping them. This point, wherever located, is termed the base line of the demonstration. This method is founded upon the principle that if the pressure at a given point is known,

and if steam does expand somewhere near Mariotte's law, then it becomes a mathematical problem, and, if we know the pressure at a certain point, we can lay out, by the means to be explained, the precise point at which a known initial pressure of steam should be cut off to realize the pressure denoted by the base line wherever it is located. This is the whole theory and it has been reduced to practice in so many different forms of diagrams, at so many different points of cut-off, under so many different pressures, and with such a variety of types of engines, that the best authorities in several of our institutions of learning have adopted it, and have pronounced it mathematically correct. We do not mean to go into mathematics to any extent, and shall, therefore, refer our readers to the various diagrams illustrated in this volume, which are founded upon this demonstration, and which embrace a large range of different types of engines at all sorts of speed, under all differences of pressure, and that the comparisons made are actual rather than visionary.

Very frequently, as in one of the first examples given in this lesson, we have found the apparent or visible cut-off, on the diagram as made by the instrument, to vary materially from the demonstrated line. To explain this briefly, it frequently occurs that the valve does not seat itself, or that some disturbance occurs in its action, so that after it is apparently closed and the expansion line has been commenced, that a quantity of steam drifts into the cylinder, so that the indicator does not make a true expansion line from the quantity of steam shown by the visible point of cut-off, and this method shows us precisely the amount of steam wasted as between visible and demonstrated points of cut-off. We have never yet found an engine with this demonstration where the actual line of the indicator overran in amount of work yielded, the theoretical line drawn from the point of cut-off from the demonstration.

Another point for the reader which may be asked, we will anticipate. It is frequently necessary (in his mind only, however,) to know precisely the amount of clearance to an engine, in order to know exactly the use of the steam. With this method of demonstration the clearance becomes unnecessary so far as the demonstration goes; it is very important, however, if we are figuring the diagram for economy in water, to know the clearance, but so far as the action of steam goes, and the reliability of the demonstration based on that action, the clearance is an unnecessary quantity. We are dealing with the steam after the expansion takes place, it shows us what the valves do and shows it correctly, but if we are to get at the actual amount of steam used, in every instance, we must then learn the clearance of the engine and add a proportionate length to the amount of steam used; but these two elements are not of necessity identified with each other so that the clearance need to be taken into account in the demonstration.

Fig. 96 is taken from a Corliss engine, which has been running many years. To explain our demonstration, we first of all draw the line of initial pressure C, then the line of absolute vacuum D, the vertical line B, which in this case represents the clearance of the engine. We have now actually known factors. Now, at some point in the expansion line, in this case at the

crossing of the expansion line with the line of rest of the instrument, we draw the vertical line A; this is also a known quantity; it is the actual pressure in the cylinder above the vacuum line, it is, therefore, a known quantity. There is no especial reason why we locate it at this particular point in the stroke, only at that point the line is entirely settled in its work.

Now, from the intersection of A, D, we draw the angular line E, which connects the base of A with the intersection of B, C, at the point representing the clearance of the engine added to the diagram and the initial pressure. This line is for the purpose of demonstration; now we wish to obtain a parallel line to the one just erected; measure the distance from A to the line just erected on the atmospheric line, as in this case the top of the line A intersects with the atmospheric line; lay off this distance A, E, on C which gives the distance F, I; lay off the same distance on the line D, which gives us D, K, or from the base line A to the new line K, F. F is, therefore, the

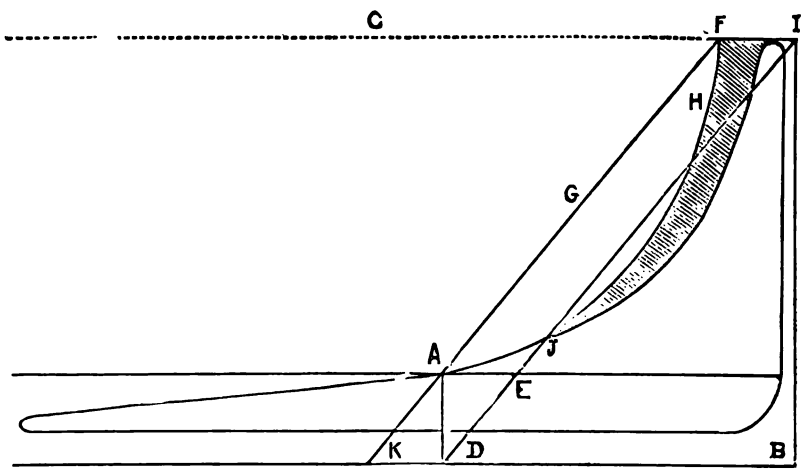


FIG. 96.

point at which the initial pressure of steam should have been cut off to have given the pressure A at that point in the expansion line. It will be seen that the fact and the demonstration do not agree apparently. This is the end of the demonstration practically. Now, if we compare results, we find that the lines of the indicator diagrams, as left by the instrument, show a very much shorter cut-off than the line F. But, at the point J, the theoretical curve dropped from the line F, joins with the actual line of the instrument, and from the point J the theoretical and the actual run on together. After the valve in the engine closes, an amount of steam passed through under it and was carried into the cylinder, and the amount of steam increased after the cut-off was shown by the indicator to equal the amount shown by the shaded portion of the diagram, between the actual line of the instrument and the theoretical line dropped from F, continuing H, J, or about twenty per cent. The point F represents the point of cut-off equaling the actual amount of

steam put into the cylinder, taking the whole diagram into account as demonstrated. The steam drifted into the cylinder from the time the cut-off valve was apparently closed, as shown by the indicator, up to that point in the stroke represented by J, where the leakage stopped, the valve then had become positively closed and no more steam was admitted.

It may be remarked that, after this demonstration had been published, the agent of the mill from whose engine this diagram was taken was written to, asking him if he would examine his engine to see whether the valve on the head end was leaking or not. His answer was:

"Yours of————————received: contents noted. I removed the cylinder head last night, and found a bad leak in the steam valve."

In contrast to this, we introduce Fig. 97, taken from the Pullman engine at the Pullman Car Works, near Chicago; the same engine which was exhibited at the Philadelphia Exhibition in 1876, by Geo. H. Corliss.

In this case we erect first the line of initial pressure, then the vacuum line. In this case the clearance is not known, and in contrast with Fig. 96 we make our base line, A, below the atmospheric line. The demonstration is then made precisely as in the former case, with the result that the motion of the valve in this case is a trifle slow as compared to the stroke, and the visible and actual points of cut-off vary slightly, but come together at the point J, which in this case is much nearer the commencement of the stroke.

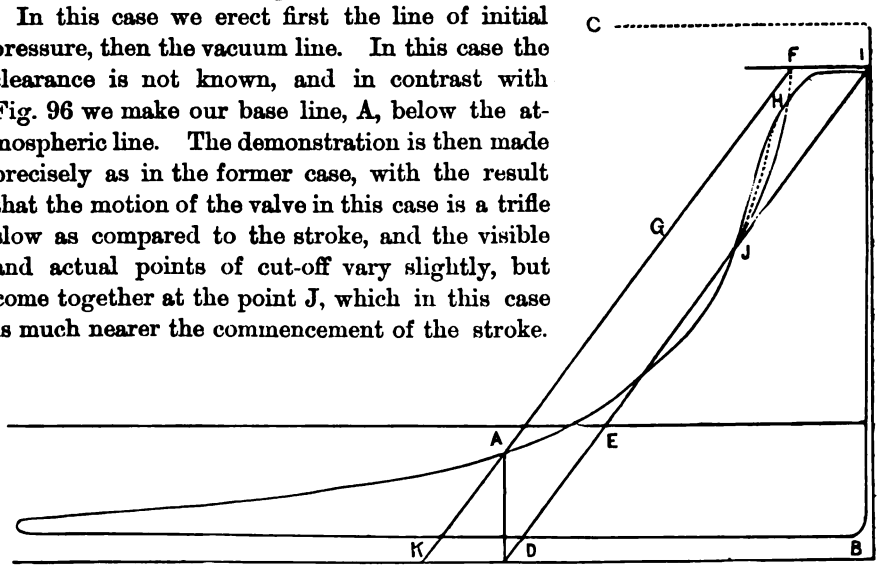


Fig. 97.

The actual and theoretical then run along almost identically. It will be noticed that there is nothing assumed in this case, and if the demonstration is carefully made, which anyone can do with a pair of triangles, you will get positive results. F, I, in this case represent the amount of steam introduced into the cylinder. The expansion line runs considerably below the atmospheric line, and the vacuum line is almost a perfect line, there being no compression. The admission line is parallel to the vertical by its side, but the opening valve is a very trifle late; or, we might say properly, is a trifle slow in its motion, so that a very slight diminution of pressure is observed. The convexity at H in this diagram is caused by a slight leak in the valve when it seats. It must be borne in mind at this time that the expansion is

in a very rapid ratio, and when J, the expansion line, has been reached, the valve is seated and not another particle of steam obtains access into the cylinder. During the time of this leak, which is insignificant, the engine makes but trifling progress in its stroke. From the point J to the termination of the expansion line, there is a variation of less than one-fifth of one per cent. from the theoretical, taking into account the realized boiler pressure there is a loss of 1.7 per cent. This engine is, therefore, realizing 98.3 per cent. of the theoretical, taking realized steam pressure as the unity.

In these two diagrams we have avoided any confusion of lines in laying out the theoretical curve. That method will be explained in the following diagrams, and if the readers of this will follow the different examples, showing the adaptation of this demonstration, they cannot fail, we believe, to become as proficient and as careful in the application of the demonstration and the theoretical curve, as anyone need to be for all practical purposes. By this method of demonstration we show, in the case of Fig. 97, 98 per cent. plus, while in Fig. 96 we show a little less than 80 per cent. of the theoretical. Either of these diagrams, without any demonstration upon them, make a fine-looking curve; it shows, therefore, that the application of some system of demonstration with a basis of fact, will give us what we are studying the indicator for—actual information with regard to some thorough and reliable test, to ascertain whether the diagrams, after taken, if good-looking, shall give us practical results, showing an economy in the use of steam as well as a pleasing appearance by comparison.

To embody the whole matter for reference, we give the following

DIRECTIONS FOR MAKING THE DEMONSTRATION.

Take any indicator diagram, lay out upon it the absolute vacuum line with the scale that the diagram was taken with. Then lay out the initial or realized pressure in the cylinders; these two lines will, of course, be parallel. Then connect these two lines at the admission end of the diagram by a vertical line at right angles to the two horizontals already laid down. If the clearance is known, this line may include it, otherwise erect it simply the width of a line away from any portion of the admission line; but this may be varied somewhat; if the engine takes steam too early or too late, let the vertical line barely be outside of the extreme point covered by the line of the indicator. Now, from some point on the expansion line near the center, if anything, a little beyond, erect the base line from the actual line of the indicator to the absolute vacuum line, and be careful to have it at right angles to the vacuum line. From the intersection of this line with the vacuum line, draw a diagonal to the intersection of the steam pressure and vertical line. Now, by means of a triangle lay off a right-angled line from the top of the base line, or its intersection with the expansion line of the diagram, until it intersects with the diagonal line just drawn. The purpose of this line is to measure carefully, with a pair of dividers or otherwise, the distance from the top of the base line to the diagonal, so that this distance may be transferred

both to the vacuum line and the steam pressure line, as the exact points from which to draw the parallel diagonal, and this parallel diagonal line must in every instance, and will if properly done, pass by the exact top of the base line at the point of its intersection with the expansion line of the instrument. Wherever this line, the last diagonal, touches the line of steam pressure, from that point drop a perpendicular to the vacuum line. You have now the precise point of cut-off from the pressure at the base line, or first line erected.

These instructions apply to the low pressure, condensing, compound locomotive, marine or any other indicator diagram, whether taken from steam, water, air, gas, so far as we have ever been able to prove it. This rule has been given to familiarize the reader, and without any letters of reference, so that the principles may be thoroughly understood. The mathematical demonstration is not necessary, we think, from the explanation which has preceded it.

LESSON XLII.

DEMONSTRATION OF THE POINT OF CUT-OFF, AND HOW TO LAY OUT THE THEORETICAL CURVE.

Fig. 98 is an interesting diagram in many respects, and only shows what the general tendency is among steam users by overloading their engines. The data with this diagram is 17 inches diameter, 36 inches stroke, 57 revolutions per minute, boiler pressure 70, scale 30. A is the absolute vacuum; B, highest realized pressure in the cylinder; C, vertical line being nominally to represent the end of the stroke, clearance not included in this case.

Having surrounded the diagram by a parallelogram, we commence by drawing the line D, which represents the pressure of steam above absolute vacuum at that point of 63½ pounds. From the intersection of A D, E is drawn to the intersection of C B. Now, from the top of the line D, draw at right angles the dotted line J, connecting D E; the distance from one end to the other of J is the distance to be laid off on the line B, as well as A for the parallel line, F. From the intersection of F B we drop G, and the length of the line, B, from C to G, is the volume of the cylinder filled with steam at the initial pressure, which should be cut off at the point G on B to produce the pressure, D, on the expansion line. This finishes the demonstration of the point of cut-off.

We wish now to erect from this data already obtained the theoretical curve, in order to ascertain whether the expansion line of the engine approximates closely or otherwise to the theoretical line. We repeat here the method given in Volume I, and shall endeavor to explain it so fully that no reference to Volume I will be required. We commence at the intersection of A C, drawing the radial lines, and to prevent confusion, we have used numerals rather than letters in this figure. These lines are drawn from the point K on the intersection of A C. In erecting the theoretical curve, the base of our computation must always be absolute vacuum. While this differs somewhat in barometrical range, it is exceedingly small, and for the moment we assume it at 14.7. We draw the lines, 1 from K to G, and the line 2 from K to the end of the line B, covering the very end of the diagram. Now, between these two lines, 1, 2, on B, we drop the ordinates at right angles to B, a little below the expansion line, at any distance apart we choose. In this case we drop 3, 4, close together; then 5, 6, 7, at a distance double that between 3 and 4. There is no special reason for making any difference in this. We sometimes drop the ordinates closer together in the first part of the expansion curve, where the greatest variation takes place in expansion, but they can be put as near together or as far apart as the demonstrator may choose.

Now, from the intersection of the ordinates, 3, 4, 5, 6, 7, and the line B, draw the radial lines from the point K to each separate point of intersection. Now, wherever the radial lines cross the line G, is the point of our next computation. From the points of the radial lines crossing the ordinate G, we next draw lines at right angles to G until they cross the ordinates 3, 4, 5, 6, 7. We have here then following out this process with each one of the lines to their crossing with G, the lines, 8, 9, 10, 11, 12, 13. Now wherever these two lines 8-3, 9-4, 10-5, 11-6, 12-7 intersect, through the points described by their intersection lies the hyperbolic curve from the demonstration.

In this case it will be noted, to return to the diagram for a moment, that we start off with an initial pressure of 70 pounds. The steam pressure is gradually reduced or, as engineers term it, wire-drawn, throttled so that it is constantly reduced in pressure on the diagram. At the point where the ordinate G is erected, we have 13 pounds less than we started with, or 57 pounds realized at that point; dropping off still further, so that at the point where D intersects the hyperbolic curve we have only 49 pounds. Now with the ordinary demonstration which has been so frequently printed, and upon which so many arguments have been based, in this diagram we should have no possible data with any sort of certainty, for ascertaining precisely where the steam was cut off. In this case, the result proved the correctness of the assumption, and the assumption is based on the fact that the demonstration is correct. The theoretical curve in this case starts from the point B, G, and strikes the actual line of the instrument at the point I, or directly over the line D, and the two lines, which are very clearly drawn (the actual line of the indicator in long dots and the theoretical curve very fine dots), pass over each other for such a proportion of the distance that the two lines are inseparable until

almost the commencement of exhaust. At the last ordinate the line of the instrument is very slightly above the theoretical line. The line D may be placed anywhere on the expansion line between the visible point of cut-off and the visible point of release; and in the case of some diagrams, which will be shown further on, it will be seen that where difficulty exists, in every one of these points the demonstration proves what the action would have been if there is any accuracy at all to the action of the valves, and a cut off was intended. In this case the action of the engine was fettered somewhat by a late release, we might say, but, as a matter of fact, while the exhaust valve could have been opened a trifle earlier, the amount of steam in the cylinder was enormous, and the exhaust is partially clogged for that reason. It will be interesting when we state that the theoretical use of steam on this dia-

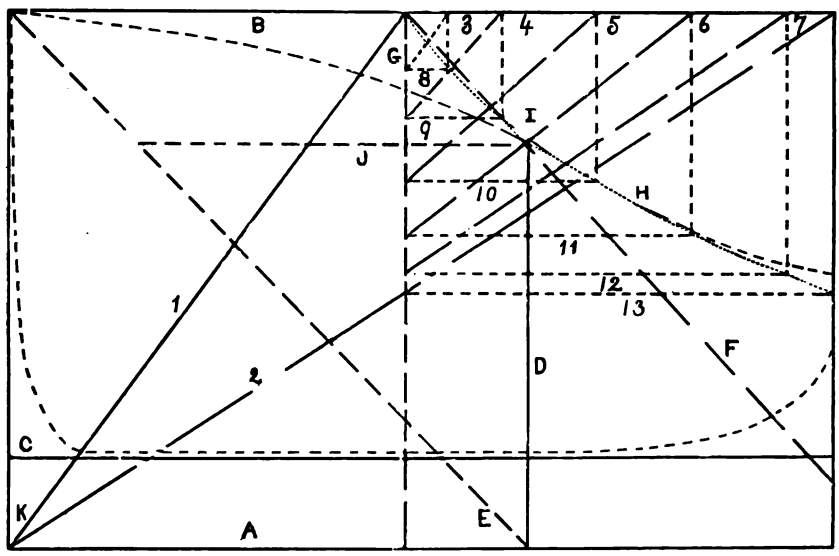


FIG. 98.

gram, Fig. 98, measuring the full boiler pressure up to the point of cut-off, then following the theoretical line, making a perfect exhaust, is 792, while the actual useful effect measured by the planimeter is 715, giving us a percentage of a trifle over 90 per cent., and yet this is by no means good practice; it speaks well for the design of the engine, but not for the management of its owner.

Referring to the demonstration of the point of cut-off, Fig, 98, as compared with Figs. 96, 97, shows almost the other extreme of the efficiency of the application of this demonstration to the every-day work of the working engineer. Any engineer with a steady hand can do all that we have been describing. A pair of steel triangles, we prefer, made by Brown & Sharpe, although rubber or wood will do, if they are taken care of, a sharp pencil, and for laying out the theoretical curve a series of curves of different radius,

which can be bought at any draughtsmen's supply place, and only two or three will be required for a very large range of work—this is all the apparatus—and a board a foot square, covered with blotting paper or coarse rope paper not sized or glazy finished, completes the whole apparatus.

LESSON XLIII.

THE DEMONSTRATION OF THE POINT OF CUT-OFF AND THE LAYING OUT OF THE THEORETICAL CURVE WITHOUT REFERENCE LETTERS.

If the two previous lessons have been carefully studied, the reader will have a pretty good idea of how to do, and what is being attempted. Fig. 99 is taken from the steamer City of Worcester, Norwich Line of New York and New England Steamers, between Boston and New York. The diagram illus-

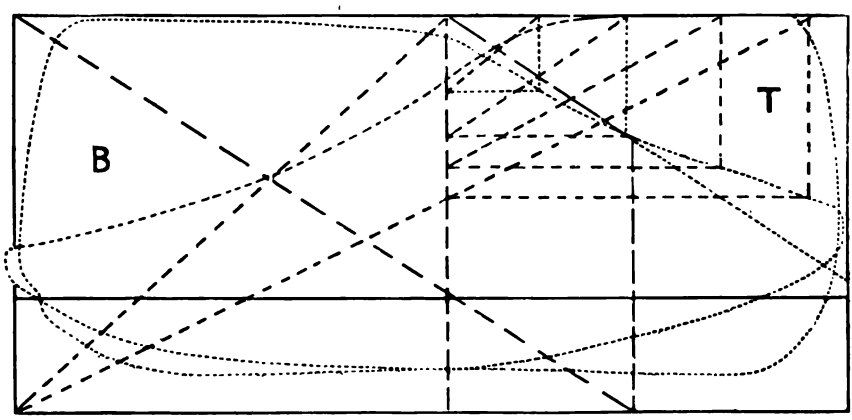


FIG. 99.

trated was taken while her engines were being adjusted and before they were fairly complete. We have chosen this diagram for the especial purpose of making the demonstration upon it, not having taken the most perfect one for that purpose. This diagram was taken while she was at full speed, her cylinders being 90 inches in diameter, 12 feet stroke, 35 pounds pressure by gauge, 22 inches of vacuum per gauge, throttle wide open, running 18+ revolutions per minute, 24 scale.

The bottom diagram in this case carries steam the greatest distance, as is usual in marine engines. We have been compelled to draw our line representing the initial pressure a very trifle above the actual, in order to allow the lines of the diagram to show, for the bottom end of the cylinder, although it takes steam late on the opening of the valve. In this case it realizes full boiler pressure after having traveled several inches, and at the point of cut-off by demonstration loses only three pounds from the initial; while the top end realizes full boiler pressure to the very point of cut-off visibly. The release as shown in these diagrams is rather late, later diagrams improved it very much; so the vacuum in this case was improved after.

The base line in this case is erected at about half-way on the expansion line. The parallels are drawn and the point of cut-off located very closely to what we would have termed the visible point. Radial lines and ordinates are erected as before stated, and where the ordinate and the line from the point of cut-off cross, it will be found to almost touch in each of the four cases, the line of the indicator as it left the diagram, so nearly at least, that we have not thought it worth while to attempt to draw in the theoretical line, from the fact that the two lines are so very close together that it would lead to a confusion in the mind of the reader. The top end of the cylinder is a little late in taking steam but not as late as the bottom; the result of this is shown in the slightly increased pressure and in the fact that the steam line in itself is much straighter than in the other end.

We desire it understood that this diagram was not selected to show the performance of the steamer; it was selected rather as a diagram, somewhat distorted, for the sole purpose of showing that the demonstration of the point of cut-off was equally as applicable to a diagram in which the lines were not clearly established, and that the result could be depended upon for practical application aside from any or all theoretical questions.

LESSON XLIV.

MODERN STEAMSHIP ENGINES EXAMINED BOTH WITH REFERENCE TO ECONOMY AND THE APPLICATION OF THE DETERMINATION OF THE POINT OF CUT-OFF, AS WELL AS A COMPARISON OF THE ACCURACY OF TWO DIFFERENT INDICATORS ON THE SAME SHIP.

Figs. 100 and 101 are from a modern steamship running between New York and————. The diagrams 100 and 101 were taken with an English instrument furnished by the builders of the vessel. There are several very noticeable features about this diagram 100. The bottom end of the cylinder gives us more than boiler pressure; this cannot possibly be, the boiler pressure as given at the moment was 78 pounds, scale 32; we have fully 80 pounds as per indicator card. The steam lines are very irregular and the expansion line, it will be noticed, is very much higher than it should be about the point of cut-off, showing first, that the steam is throttled in the passage-ways, and next, that the valve closes slowly and continues to admit steam. The stroke of the engine is 54 inches. We have located the point of cut-off from the usual demonstration and it will be noticed that the curve from the release, following up the expansion line, denotes where the steam to have been cut off, would have given the theoretical line following the expansion the majority of the way.

The release of the engine appears to be very good, and it is at 38 pounds above the atmospheric line, but there is something very curious about the exhausting of the engine from either end, with reference to the positively straight line A, B, while as a matter of fact such a line as this, where the receiver is used as between the high and low pressure cylinder, cannot be made, if we are to have any faith in modern engineering. It shows, therefore, that there must be something wrong with this indicator, and if we come to analyze it a little further we shall probably find it. By the indicator, the steam valve closes at $29\frac{3}{8}$ inches of the stroke on the bottom; this gives us an indicated horse-power of $1255\frac{1}{2}$. The exhaust valve closes on a receiver pressure of 19 pounds at four inches before the end of the stroke, while on the top end the exhaust valve closes at $5\frac{56}{60}$ inches, the top giving 1129 horse power.

If we compare this with the low pressure, Fig. 101, the line B represents the pressure of steam in the receiver, while the line A represents the realized pressure on the piston, which is 11 pounds, while the receiver pressure is 19 pounds. We have made the demonstration upon the top end showing the cutting off at $26\frac{1}{4}$ inches of the stroke, giving 1293.72 horse-power, while the bottom end gives 1341.93 horse-power. Only about half the receiver pressure

is realized, that is carried one-half stroke and shows a very fair performance. The vacuum only 18 inches is realized as the extreme, giving 9 pounds.

For the sake of comparison, Figs. 102 and 103 are given, taken from the Improved Thompson indicator, the American Steam Gauge Company's build, from the same ship, arrangements previously being made; these followed 100 and 101 as soon as the instruments could be changed, the ship running under the same pressure of steam, same number of revolutions, smooth water. Here we have a decided contrast. Fig. 102 shows the high pressure cylinder, and we have here erected three different curves. A, Fig. 102 is the theoretical curve from the arrow-head in the line D, which shows that that cylinder actually used steam sufficient to cut off at $25\frac{7}{10}$ inches, giving an effective horse-power of 988.2. B is from the initial pressure 78 pounds, scale 40, and shows what was expected of the engine, while C is the theoretical curve from the terminal pressure showing quite another result. The line B shows what was expected, viz.: to cut off at one-third and to realize boiler pressure. We find, however, the terminal pressure of the diagram is 27 pounds above the atmosphere, while the terminal pressure of the curve from the supposed point was 20 pounds above the atmosphere. The line C shows the engine to have cut off at $21\frac{45}{100}$ inches of the stroke, if the terminal pressure was right. It will be seen that the diagram upon which the two curves are erected, only realizes 70 pounds of steam, and that at one-third stroke 12 pounds less than that is realized on the piston head. The line A, as drawn from the data given, shows about the actual performance of the engine cutting-off realized pressure at 25.7 inches, developing 1075.73 horse-power. The dotted line E, if continued, would barely touch the end of each diagram, and shows the rise in pressure in the receiver, between the commencement and middle of the exhaust, amounting in this case to about $7\frac{1}{2}$ or 8 pounds. The minimum amount of pressure in the receiver in this case is 9 pounds, the greatest amount $14\frac{1}{2}$ to $15\frac{1}{2}$.

Another point engineers often require has been carefully figured on the right-hand diagram where B and C are shown, the exhaust valve of the high pressure engine closes at 5.2+ inches before the end of the stroke, while on the left hand diagram the exhaust valve closes at 7.8+ inches.

Fig. 103, scale 10, realizes a trifle over ten pounds of the receiver pressure. In this case, we have applied the demonstration from the average of the expansion line, as nearly as we can judge. The action of the valves, in this case, shows plainly the change in pressure in the receiver from the commencement to the middle of the exhaust. The steam line is a very peculiar one, and the demonstration shows that the valve was closed at 21.7 inches of the stroke, giving a horse-power of 1042.4, while the other end gives 1143.48 horse-power. There are one or two points with reference to this diagram worthy of notice. On the left-hand diagram the exhaust valve closes at 11.85+ inches of the stroke, at a lower pressure than the right-hand end, which closes at 10.53 inches of the stroke. The cushion or compression, in this case, plainly shows that the higher pressure and shorter closure produced the

highest compression. The vacuum shows a trifle over ten pounds at the highest, the lowest being eight.

Diagrams 100 and 101 show the total amount of power required to drive the ship as 2510.09 horse-power, while 102 and 103, taken within a very few moments of the others and as near as possible under the same circumstances, show the probably correct action of the valves, and the correct amount of power as 2124.94 horse-power. 102 shows plainly the rise in the receiver or exhaust line, and 103 plainly shows this action in the steam and expansion line of the right-hand diagram. Experiments are now being conducted on that ship with a view to adjustment and finding where the engines will do the best work. We would not attribute any motive, but it is somewhat curious that the indicator furnished should make a difference of a few hundred horse-power in the power required to drive a ship, and, therefore, presumably make the amount of fuel per horse-power less than if the actual amount of power was known to be much less than it was supposed, and the amount of fuel much more than it had been considered. These diagrams are well worthy of a careful study for they will interest stationary engineers as much as marine. We should have grave doubts as to the economy of these engines as compared with some of the examples from other engines which will follow.

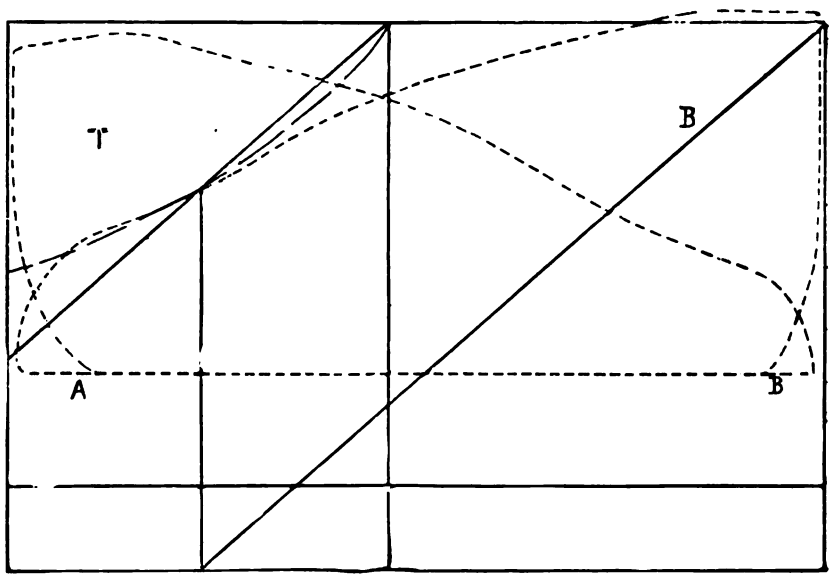


FIG. 100.

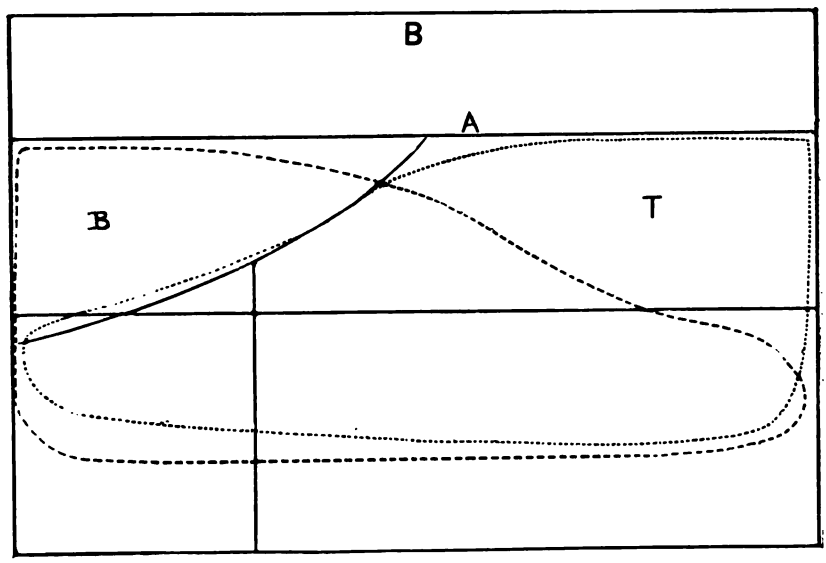


FIG. 101.

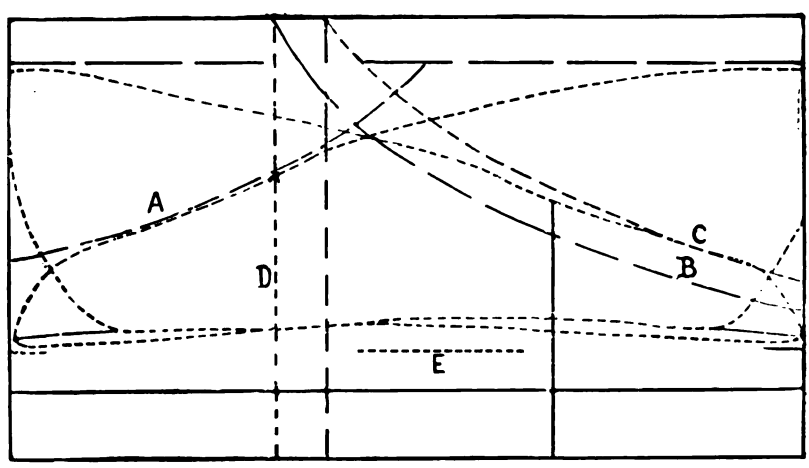


FIG. 102.

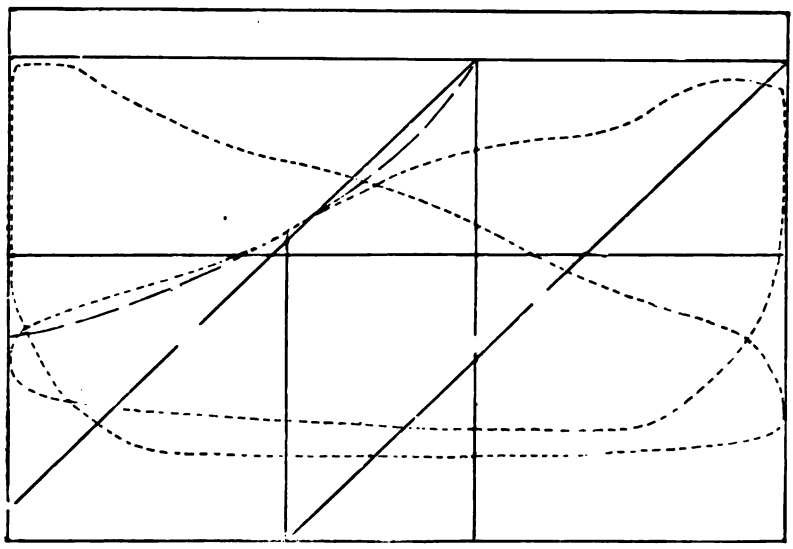


FIG. 103.

LESSON XLV.

BADLY THROTTLED ENGINE, LOSS IN INITIAL PRESSURE, AND LOSS IN VALVES.

The diagram Fig. 104 is from an engine sixteen inches cylinder, thirty-six inches stroke, running sixty revolutions, boiler pressure eighty pounds,

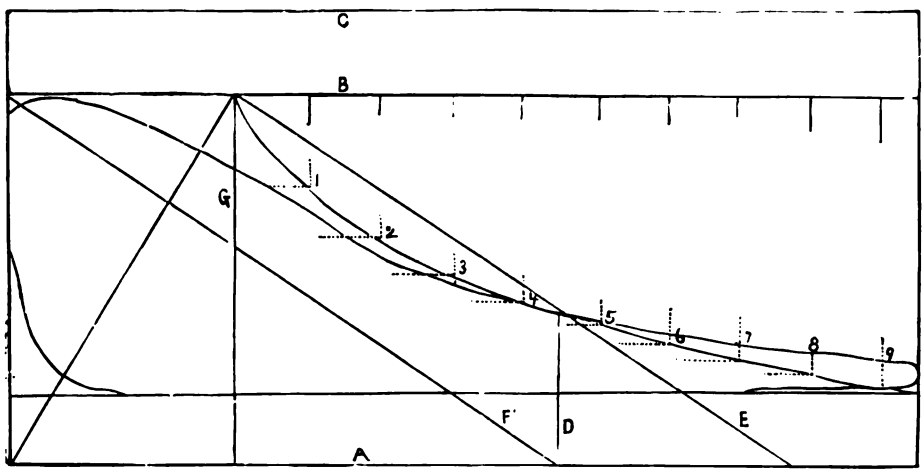


FIG. 104.

scale forty, with a three-inch feed pipe and a five-inch exhaust pipe. There are points of interest about this diagram well worth examination.

A represents the line of absolute vacuum, B the line of realized pressure, C boiler pressure. It will be noted there is a wide difference between the lines B C; for with eighty pounds boiler pressure, there is only 62½ pounds initial pressure, the steam valve opens slowly, and we doubt if it ever gets wide open, judging from the steam line. From the diagram there is nothing positive to tell where the point of cut-off is, so we must resort to the demonstration to gain information. In this case we erect the line, D, rather past the center of the expansion line. We then draw the first parallel, F, from the intersection of D A to the intersection of F B. The line E is then drawn parallel with F from A to B. Wherever the line E touches B, from that point drop an ordinate G, which represents virtually the volume of steam admitted to the cylinder to do the work, and this line measures the amount of steam, from the commencement of the stroke to its cutting off, that was used to produce the known pressure at D, supposing the steam had been properly put into the cylinder and that valves and piston were tight so that it was correctly handled after it was once put there; but, unfortunately, the steam did not get in on the piston as it should have done. Now, had the proper amount of steam been correctly applied between the introduction and the line G, it would have followed out the line B to the point B G, and then would have followed the theoretical line or the dotted line. But in the first place we see that it falls away short of the theoretical line until it reaches the fourth ordinate; at that point it seems to go above the theoretical line, we find at the ninth ordinate it commences to exhaust at the very point where it should have expanded to.

To refer again to the demonstration and its purpose, this application is not at all to raise questions to confuse the engineers, but rather to show them different points which arise in our own practice and that of others, where so many of these things are constantly coming up which vex the operator and the builder. In this case it is perfectly fair to presume that the stream drifted in after the valves commenced to shut, gradually ran down on the line G, until the expansion is five pounds at the first ordinate below the theoretical line. This theoretical line is based on the actual pressure of steam at the line D, or the base line, so that the pressure at the first ordinate should have been five pounds more than it is; at the second ordinate plus three pounds more than it is; at the third ordinate two pounds; at the fourth ordinate the lines virtually run together; at the fifth ordinate the theoretical line runs below the line of the instrument; at the sixth ordinate still more below; seventh, eighth, and ninth increase until we stop at the ninth ordinate five pounds above the line, as we were five pounds below at the first, while the distance from the base line D to the ninth ordinate is about the same as that of the ordinate G.

Now, what is the cause of this almost exact balancing of the figure? Why has it been below in one point and above in the other? There are two reasons that could make it so, and the indicator cannot tell us which of the two it was.

In the first place the pressure actually was below what it should have been; in the last, it was above. Now, this pressure may have been caused by a leaking-by of the piston or valves, and in the one case it would account for the terminal pressure at the ninth ordinate, probably to be more like a leak in the valves; or, if the steam was wet, there might be a certain amount of re-evaporation which would tend to keep the pressure a little above its theoretical value or its real value. This shows how unfair it is to base any absolute demonstration on the terminal pressure, as showing the real action of the engine. If the piston had been leaking-by during expansion to any such extent, the leak would have shown on the exhaust of the other side, and as it did not, we know that the opening of the valve was insufficient from the dropping of pressure below B on G at point of cut-off, and also that the pressure at B, cut-off at G, gives us the volume of steam to give the pressure, D, at that particular point in the expansion line, and that the valve was slow in closing, or, when closed allowed steam to pass through, or, leaked sufficient steam to raise the terminal pressure as shown, wasting the 62½ lbs. of steam realized in the cylinder by valves insufficient in area and probably insufficient in their relative motion to give steam for the speed of the piston at the regular speed of the engine.

LESSON XLVI.

HIGH-SPEED ENGINE DIAGRAM.

The diagram Fig. 105, in this lesson was taken from an Armington & Sims engine, 8½ inches diameter, ten inches stroke, running at 320 revolutions per minute, boiler pressure seventy, Thompson improved indicator, forty scale. The load in this case was given by a lever bearing upon the under side of the balance wheel, and in several instances the load varied by intention from the mere friction of the engine to 25 or 28 horse-power, within a quarter of a minute. At the particular instant when this diagram was taken, the load was constant for the sake of ascertaining the accuracy of the indicator, and this was only one of several diagrams in the series, and this particular diagram is chosen in order to show the largest range of variation recorded; in other words, the worst diagram of the set.

The admission line at A will be seen to vary a little from the vertical line, whereas at B the impact given by the admission raises the pressure somewhat, and at the same time is a trifle late as compared with the movement of the piston. The oscillations, it will be seen, are confined, and the steam line,

when fully drawn, stands at sixty pounds, maintaining fifty-seven to the point of cut-off at C. It is a curious fact that some makers of indicators are recently claiming that the expansion line must be *without* oscillations, similar to those shown in this diagram, in other words, their instruments draw in the hyperbolic curve perfectly. In this case we wish to call the attention of our readers to the fact that a number of elements are at work between the points C and D, in order to prepare them to reason out in their own minds as to whether our own ideas upon the subject will bear the application of reasoning from the stand-point of fact.

This engine is traveling very fast; at the point C the valve is closed or very nearly so; every thousandth of an inch that the piston moves forward on its stroke increases the volume of the cylinder; no more steam is being admitted; an increase of volume means a decrease of pressure; a decrease of pressure means a decrease of temperature, and a decrease of temperature means, when applied to steam, an increase of water present in the cylinder. Now the ratio of the volume of the cylinder is increasing all the while after

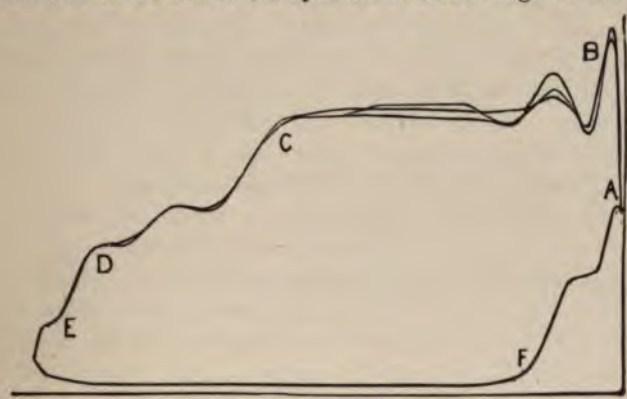


FIG. 105.

the valve closes; the volume increases, the pressure decreases, the water increases, etc. Now, is it possible for steam—supposing it was a perfectly dry steam at this point, which it is not—is it possible to make any instrument that will make any portion of a hyperbolic curve when these several elements are each one working negatively upon the other? Even after the release commences, which is at D, it will be found then that the variation of volume, temperature, etc., make a still further fluctuation in the line at E, by which time the exhaust port is fully open. We shall show, in a subsequent lesson, that it is not precisely the correct theory, if men are to make truthful indicators.

Now, added to the elements that we have cited, there is another very important one, the expansion and contraction of the metal, the weight of the piston, change in the spring, the friction of the moving parts, which is but extremely little, yet it is something. Perhaps some one can tell us how it is possible to make an indicator tell an untruth, or in other words, make some portion of the hyperbolic curve from C to D, instead of the undulating line, which is

without doubt caused by the various elements to which we have referred, and it is somewhat curious that when the exhaust valve closes near F, in the compression of the steam, the increase of density or pressure by shutting the steam up and compressing it brings back certain units of heat, and that the compression line has certainly, in the same ratio, given us the undulations in an inverse way, (showing compression) to what the expansion line from C to D is. Compare the lines F A and C D, and tell us why these changes should take place, one proving the other. It will be noticed that the undulations in the line are reversed in F A to what they are in C D, showing that the expansion with the indicator piston upon the steam is very correctly noted, while on the other side in compression the steam is driven up against the piston, showing the same effect precisely, but that the directions of the lines are reversed.

The diagram shows a very good use of steam; possibly the action of the steam valve should be quickened a trifle in its relation to the piston of the engine, that would make a somewhat sharper corner at the termination of release and commencement of exhaust, and would also carry the compression a trifle higher and avoid the little hook at A, or in other words, would run the compression line into the steam line and would bring the point B nearer the vertical line shown. Taken all in all, it is a beautiful specimen of the high-speed engine diagram as well as of the indicator's work. The three lines, as shown in the original, are carefully reproduced in all their variation, and the subject of the maintenance of pressure, quick expansion, almost locomotive release, as well as locomotive compression are well executed and illustrated, but with the full effect of boiler pressure to the point of cut-off, or a close approximation to it, and a fine exhaust, both showing that boiler pressure and free exhaust can be realized in this type of engine, and are accomplished in every-day work.

LESSON XLVII.

MEDIUM HIGH SPEED ENGINE.

Fig. 106 is from a different type of engine, one of medium high speed, which has not been running many months. The diagram is from the Buckeye engine, twenty-four inches diameter, thirty-six inches stroke, 100 revolutions per minute, condensing, one of a pair, front end of the left hand. Boiler pressure seventy-two, scale thirty, Thompson improved indicator.

Some pains have been taken to make the demonstration as plain as pos-

sible in this case, for those not familiar with the new method of laying out the point of cut-off, and then applying the theoretical curve for efficiency, or to detect leakages or other troubles.

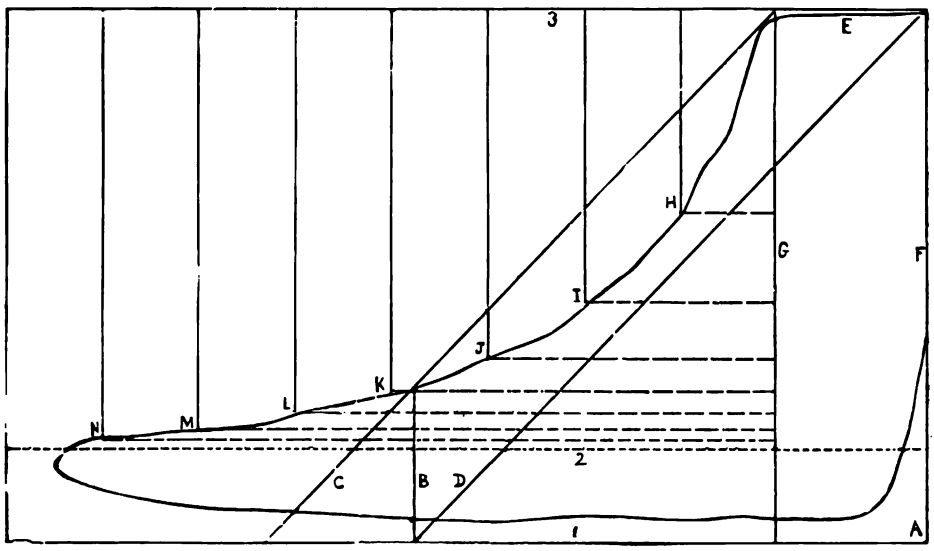


FIG. 106.

On this diagram, 1 represents the absolute vacuum, 2 the atmospheric line of the instrument, 3 the line of realized pressure in the cylinder, which is sixty-eight pounds plus, or a little less than four pounds below that of boiler pressure at the instant of taking. B is our base line from which the whole demonstration is made with reference to the point of cut-off; B is drawn from a point a little to the left of the center of the line of expansion, from that to the line of absolute vacuum. From the intersection of the lines B, 1, the line D is drawn to the intersection of 3, F, representing respectively the realized pressure in the cylinder, the line 3, and F, the admission line. In this case we do not know what the clearance is, so we have assumed nothing, but that the indicator made exactly the lines showing the work done, so that no clearance is included. We show the steam used, and as we do not know what the clearance is, we prefer to call it an unknown quantity.

C is drawn parallel to D exactly, starting from 1 and crossing the end of B at its intersection of the expansion line. Wherever this line C strikes on 3, that is the mechanical point of cut-off, assuming only that geometry is correct in its application, wherever the intersection of C, 3, comes, there is the point of cut-off, which in this case is perceptibly a trifle longer by the instrument than by the demonstration; we do not believe in the system of ordinates or logarithms where pressure and temperature are combined, but we believe if a mechanical demonstration is capable in any one direction, that a mechanical demonstration is far better for us to locate our point of cut-off, and not

be guessing, supposing, assuming, etc., etc.; hence we make the whole of our demonstration mechanical rather than by assumption.

We have, therefore, the intersection G, our first ordinate with the line 3, is the actual point of cut-off from that part of the expansion line where we have located the line B, from the point A all these lines radiate. (See Lesson XLII in both demonstrations.)

We locate the point of cut-off mechanically, and then demonstrate the theoretical curve mechanically, so that we notice here a variation of far less than the width of the line, it shows us clearly that the valves of this engine must have been working very nearly tight. Practically they are tight, and wherever any broad variation from the actual line of the theoretical curve from the point of cut-off with this demonstration occurs, you may commence at once to look for leaky valves, piston rings or something of that sort, in this case it means nothing; we are without the clearance line, and this diagram, as it stands, is simply and purely an actual exponent of the work being done at the time, but it does not show the whole bulk of the steam used, only as we know precisely what the clearance of that end of the engine was, but for all practical purposes we would not give a farthing to know, and it may be well to say here that the clearance, *if known*, would add its volume to steam used, but would in no way affect the cut off, or expansion. We have a diagram here which shows a very fine working of steam, so far as taking, carrying, cut-off, expansion and release go. The vacuum might, perhaps, be improved in amount, but as it is an independent condenser and no part of the engine, we do not criticise it. It starts with only four pounds, runs down to nine, ten, eleven, then commences to go the other way, making a fine compression, though possibly a trifling steam lead.

One point must be taken care of in locating this basis for the demonstration, and that is, that the ordinate B should never be drawn too early in the expansion line, for steam, like any other body where work is being done, as a steamship or a train of cars, takes a little time for the engine to get to pulling, and so it takes a little time for the steam to settle down to its expansive work, and that place which is fair for it, all things considered, is a trifle beyond the center or when the speed of the piston is very slightly diminished by getting up on the crank; in other words, where the speed of the piston is very slightly slower and the pressure of steam has very considerably diminished; sometimes sudden fluctuations will be found in expansion line by rings leaky, in such a case get two or three points and demonstrate from each, and so find where the leakage occurs.

LESSON XLVIII.

EXPENSIVE USE OF STEAM. COMPARISON BETWEEN EXHIBITED FACT AND POSSIBILITY.

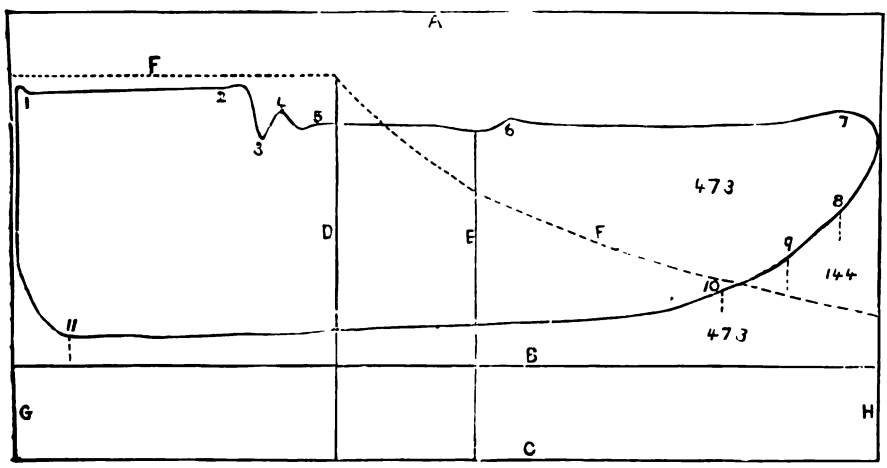


FIG. 107.

In Fig. 107 we have something not only to think of, but something which we can compare as between the application of geometry to fact and mathematical rendering of the geometrical delineation, by so simple a process that every reader who has a planimeter can, in fifteen minutes, tell whether our statements are correct or not. We have chosen about as awkward a diagram as we could conveniently, for two reasons: almost anybody who has been reading our indicator articles for the past few years, can make a demonstration on a finely-outlined indicator card; and we have chosen this curiosity more for the sake of the application of our own method of finding out, first, where the steam was cut off, and then finding out what ought to have been done. A represents the line of boiler pressure, which is far above the realized pressure in the cylinder; B represents the atmospheric line of the instrument; C represents absolute vacuum from which all computations are made both for geometrical demonstration of the point of cut-off, and quite another demonstration having nothing to do with the first, which gives us the theoretical curve, supposing steam does expand either according to Mariotte's law or Rankine's formulas; but the two demonstrations are not in any way connected, beyond that the line D shows the amount of steam used in the cylinder, the volume from C to D being filled, if cut off and properly expanded, and the intersection of line D with the line F shows point of cut-off on the

line F. The engine from which this was taken was running eighty-two revolutions per minute, scale thirty, governed by one of the throttle governors and was supposed to be doing good work. The card made by the indicator starts off with forty-five pounds initial pressure, makes a nice little jog at 1, runs along at forty-five pounds, and commences a peculiar gyration at 2, dropping off suddenly from this point to 3, rising again to 4, and making a peculiar short curve, commencing at 5 again to run in a straight line, and at 6 another peculiar vibration. The terminal pressure at 7 is forty-one pounds. We have thus a very peculiar expansion line, and almost any one with any knowledge of steam enginery would pronounce it not by any means a model card, but we have less to do with this than with the next factor in this most interesting case. A little beyond 7 the exhaust valve commences to open and opens slowly, so that at 8 we have twenty-four pounds back pressure, at 9 we have seventeen pounds and at 10 ten pounds. The back pressure gradually becomes less until the exhaust valve closes at 11, where it has been reduced to five pounds; we have all the space bounded between the exhaust line of the instrument and the atmospheric line of the instrument B, making a large area, the exhaust being, perhaps, a little less ragged than the upper line 1 to 7. The closing of the exhaust valve at 11 is very nearly correct, but the opening from and after 7 shows distinctly that the motion of the valve is incorrect, for it is entirely too slow, if large enough, in its proportion to the stroke, and all the area when open is not sufficient; hence we do not realize the theoretical line of exhaust, nor indeed the usual exhaust of a half pound of back pressure. The planimeter reading of the indicator card precisely as it comes from the instrument is 473; the planimeter reading of the area covered in by the back pressure is 144; then we have an area of 473+144=617. Now there are parties in the world who claim (we will call this horse-power) that in this case the 473 horse-power is transmitted to the machinery, and that the 144 amounts to nothing. Perhaps this is so. All engineers know that the boiler capacity is invariably measured from the atmospheric line, and in this case the boiler would receive credit for and would actually be doing 617 horse-power. It is claimed also that the back pressure upon one end equalizes the back pressure on the other; perhaps this is so; possibly not. Now, while the piston moves from 1 to 7, the steam is escaping from the other side of the piston, and from 7 to 11 is going on, on the other side of the piston. Now, if we have 473 on one side of the piston, 144 added to it, if it were working as it should, but, in this case, working against it, does it require anything on the other side of the piston to push that 144 out of one side of the piston and out of one end of the cylinder, while the steam is making the card upon the side of the piston in the direction of from 1 to 7? Now, if this statement is a fallacy will somebody show us where? In other words we have drawn the line E from the expansion line or steam line, whatever it may be, to the line C; from the base of E we have drawn a line to the intersection of F G, namely, realized pressure. and the boundary line of the card, giving the steam and vacuum lines, parallels to this line, which is omitted in the engraving. We have drawn from a point on C to

the line F, which crosses the line F at the intersection of D F; from this point we drop the line D. Now, the space bounded by the line C G F D represents the volume of the cylinder at which steam should have been cut off in order to produce its equivalent at E. Then by the same plan given in Lesson XLII, we draw in a theoretical line F. Now, we assume here simply that had the engine been handled as an engine should have been, it had a pound or so above the actual initial pressure, that it would have been cut off at D on the line F, and then if the valves were tight it would have expanded according to the curve F, and if it had exhausted as it should have done, it would have returned upon the line B. There is something curious about all this. The dotted steam and expansion line with the correct exhaust gives us precisely the same planimeter reading as in the diagram above 473 without the 144 back pressure. This may be the correct way of working engines, we mean the actual diagram, but in our own demonstration we have only shown what the engine should have done, providing the steam were worked correctly and at the real boiler pressure instead of that which was realized. It is a little curious that this result comes out precisely as it does, without any calculation other than that all the simple demonstration and the addition of about one-third of an inch in length for clearance. The comparison shows a most expensive mis-application of steam.

LESSON XLIX.

A HIGH SPEED ENGINE, RUN AT A LARGELY INCREASED SPEED TO TRY AN EXPERIMENT WITH THE THOMPSON IMPROVED INDICATOR.

The author was among the very first of the engineers who had actual experience with the high-speed type of engines, beginning with Mr. Porter's engine in 1869, and has had much to do with and has advocated the high speed for certain purposes, and it would seem, perhaps, better if we were to give some few illustrations which have not been previously given. In Fig. 108 we give something which we believe never before done, and in this case was done for an experiment, but we presume will soon be adopted as practice. It is a well known fact that in electric lighting long-stroke engines have in some cases proved to be (even with the best regulation) very undesirable, from the fact that on the incandescent light the strokes of the engine can be counted with the utmost precision, if any one will give careful attention to it. On the other hand, with some high-speed engines the short stroke has been a

disadvantage, by means of not thoroughly overcoming what was expected in the matter of measurement of time as between the long and short stroke, and the high-speed engine requires a great increase of accuracy, if such a thing is

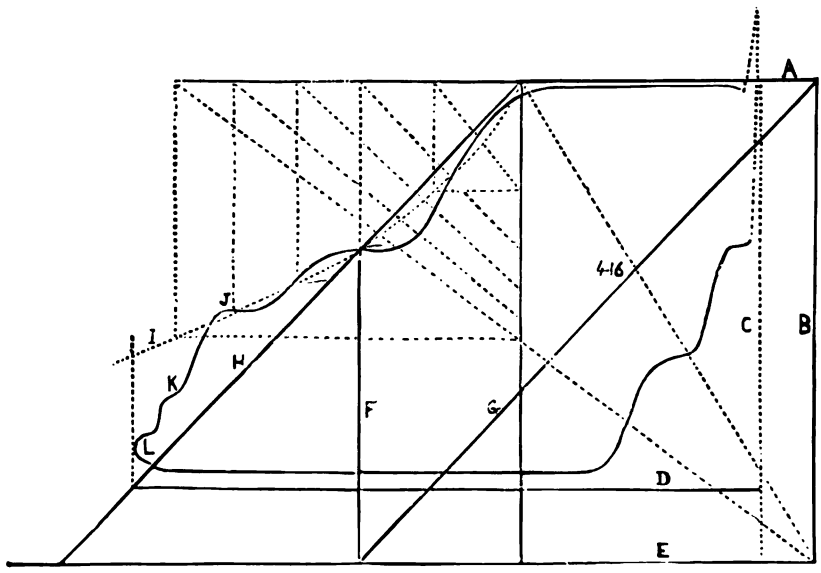


FIG. 108.

possible, over the slow speed, in proportion as the stroke is shorter, than the slow-speed engine. The same factor of an increase of speed from the commencement to the middle of the stroke, and the decrease of speed from the middle to the end of the stroke, is present in the short-stroke engine, but it becomes beautifully less in percentage as the stroke is shortened and made more frequent. In other words, the visible effect on a high-speed engine, if run at regular speed, is exceedingly little. Regular speed does not mean a great variation, but a close approximation to a certain line, and any variation from this is very noticeable indeed, and is not only noticeable, but has a very pernicious effect upon the film of the incandescent lamps.

The author was called upon to make a test with some indicators. He had desired very much to obtain an indicator that would give a reliable card from an engine running 500 revolutions. We had no engine running 500, nor could we get access to one, but through the courtesy of the owner of an engine we were allowed access to his engine during the noon hour, with the privilege of running it into the afternoon if we would agree to stay by and take care of it. The regular speed of the engine was a little above 300 per minute.

We set the regulator arm-springs down as much as we dared to, adjusted our indicators as nearly as possible, and opened the throttle valve. We had intended to run at about 400, but were simply guessing at the tension of the springs. The speed was simply terrific; counting was entirely out of order,

and the engine ran as smoothly as at 320. Finally the gentleman who had invented the 500-revolution-per-minute engine decided that he would experiment somewhere in the neighborhood of the speed we were using. A counter was then procured, and we found that our speed ran in fifteen seconds 109, thirty seconds 217, one minute 435, and two minutes gave us 866.872 and 870. The steam was then let into one of our new Thompson improved indicators. Fig. 108 is one of the diagrams taken from the head end of an Armington & Sims engine, 8½x 10, 435 revolutions, boiler pressure 90, scale 40. A represents the line of boiler pressure 88 or initial pressure, C the vertical line at right angles to D, which is the atmospheric line of the instrument, and E the line of absolute vacuum. In this case the line of the diagram above C, where the compression closes and the steam valve opens, shows that the steam valve is slightly in advance; in other words, that there is a little actual lead. The opening of this valve is instant, and the steam in this particular case shows an impact rising of between thirteen and fourteen pounds, but it as instantly descends to about four pounds below realized pressure. The steam line is then carried off very handsomely, and the visible point of cut-off is, we think, for such a speed, very plainly shown.

Here comes up the old question of what makes a wavy line of expansion, and we do not think we have far to seek in this for the reason. In this diagram there is no assumption, for we have all the facts, and the expansion line, as is shown in the first dropping after the cut-off valve has closed, descends something below the theoretical, then rises slightly above, again falls slightly below, and just before the exhaust valve opens at J, the theoretic and the practical line in its oscillations cross each other absolutely. The sudden outlet from J to K shows us that the steam will expand in anything but a section of a hyperbolic curve, when allowed free egress. At K we have another little oscillation, another sharp curve approximating much nearer to a right angle with the theoretic curve, and at L we have still another oscillation. The cause of this we have frequently been asked for, and lately in a case where the same factor appeared. Our reasoning of this is: From J to K, when the exhaust valve opens, there is a sudden exit of a considerable volume of steam under a pressure of thirty-three pounds above the atmosphere. The exhaust pipe in this case is of quite a length and when the steam from the cylinder, released by the exhaust valve, impinges upon the steam already moving in the exhaust pipe, a little reaction is caused by this very elastic medium, which makes a crook in the line at K. The steam then moves along again, that which is being released from the cylinder striking or pushing the other, all of which is very elastic, and at L the pressure is reduced so materially that no further vibration in the movement of the body of steam can be recorded by the indicator; and this may be further proved, perhaps, by the dropping off of the line as it turns from the termination of the exhaust just below the letter L, dropping down nearly two pounds before the exhaust line starts on its continuation. The line then, it will be noticed, drops a little as the exhaust is completed and before the exhaust valve closes again, a little to the left of D. Here we have precisely these same vibrations or oscillations or changes as the

compression increases, showing plainly that the exhaust valve closes and the compression ceases in amount of pounds, making a nearly straight line on the upper step before the steam valve opens.

Proceeding with our usual demonstration, first to find the point of cut-off and the actual amount of steam used, we have erected here the line F, and, if the reader will notice, we have erected it not at the point of lowest pressure, but at about the highest point after the expansion really gets settled. From F we carry the parallels G H, and in this case we have included the actual measure of clearance of the engine, embracing the inside of the valve, the passage from the valve into the cylinder and the actual space between the piston and cylinder head, from data obtained from the engine when still and the clearance filled with water. We have therefore drawn G from the intersection of F E to the intersection of A, line of boiler pressure, B representing between C and B the actual amount of clearance as compared with the total cubic contents of the cylinder through which the piston moves. In this case it will be noticed we charge the engine with the absolute boiler pressure; we also charge it with every particle of clearance at that end of the cylinder.

Having thus defined the point of cut-off, we draw the first ordinate from A to angle formed by E B, see lesson XLII, starting from the intersection of the lines B E, and we have made the whole demonstration except the point from which the lines radiate, and these are omitted purposely in order to show clearly just what the effect of the action is; from the joining of the second ordinate with a line at right angles to the first ordinate at the crossing, and the process being repeated by the third, fourth, fifth and sixth ordinates through these points from the first ordinate the theoretical curve is dotted. It will be noticed that the second ordinate of the theoretical curve crosses a trifle above the actual line of the instrument, and at about the center of the stroke or when the speed is at its very highest. The third ordinate crossing is a trifle above the line of the instrument, the fourth is a trifle below, the fifth is absolutely on the line.

At J the exhaust valve opens and the curve is carried forward, passing I, in order to show where it would have come had the pressure been maintained by keeping the exhaust valve closed. We have not figured this for absolute effective percentage, though the percentage is very high, but present it as an example from actual practice, showing that we may charge the engine with its whole clearance, about nine per cent., remembering that the cylinder is $8\frac{1}{2}$ inches in diameter, and that while the clearance may be large in proportion, the handling of the steam, charging everything to the engine that we may properly or justly do, is most excellent, even at this tremendous speed. It is impossible at such a speed as this to take a card quite so neatly as we like to do from one running 80 to 125 per minute, for if you touch the paper at all you must necessarily make several records. In this case the lines did not vary the width of one another apart at any point of the diagram, so that we have engraved a single line.

The question of the recording of the lines of expansion of steam under pressure and the oscillations is, to our own mind, always an evidence of extreme sensitiveness and reliability in the indicator, and we believe that, sooner or later, the real doctrine of the expansion of steam will be settled upon a basis that will not be filled with vagaries.

LESSON L.

CARRYING STEAM FULL STROKE AND EXHAUSTING UNDER EXCESSIVE BACK PRESSURE.

In Fig. 109 we have a comparison of high pressure steam, throttled down and then carried full stroke, and, to make the matter all the worse, the exhaust is nearly equal in resistance to the whole amount of work transmitted. We have made some comparisons on this diagram, both from the boiler pressure and the realized pressure, and to show how the effective use of the steam is entirely done away with and no economy attained. Boiler pressure, 100 lbs.; revolutions, 114 per minute; scale, 60.

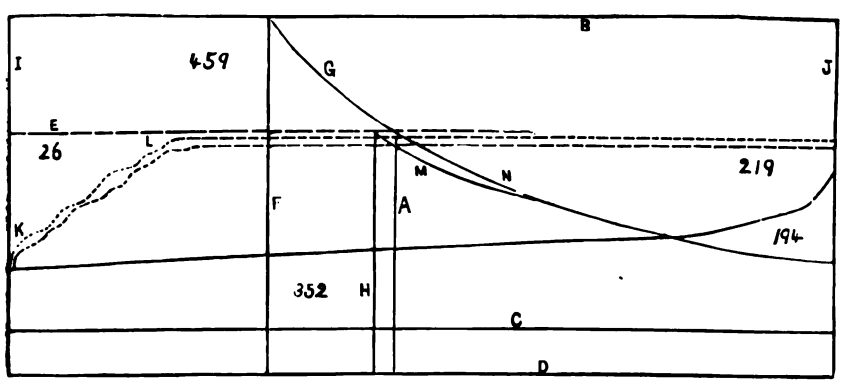


FIG. 109.

The line A in this case is the base of the first combination, B the line of boiler pressure, C the atmospheric line of the instrument, D the absolute vacuum. From the intersection of A D, we draw a line (according to our method of delineation) to the intersection of I B, then on D we lay off

towards J the same distance that exists between the intersection of A and the steam line of the indicator card and the line D I. From this point on the line D we find the point through the top of the line A which intersects B, from which we drop F, showing the amount of steam used in the cylinder to make the theoretical expansion curve G, showing the amount of steam at 100 pounds cut-off to make very nearly the same amount of work as that shown by the indicator diagram and the back pressure; the planimeter reading of the indicator diagram outline is 219, the back pressure 194, the sum of the two being 413, while if we take 100 pounds of steam, cutting it off so that A shall equal the pressure at that portion of the stroke, we obtain 459. Now there is a point here to be considered; if we were to make the outline bounded by cutting off the hundred pounds at B F, taking in the theoretical curve G, we have 459 on the planimeter. Now, if we should make the same misuse of steam by the valve in the larger feature, or by cutting steam off in admitting steam, that the indicator card itself makes from K to L, the sum total of our areas should be exact. In the case of cutting off the 100 pounds of steam, we have simply assumed that the cylinder is to be filled at the commencement of the stroke; so that while with 100 pounds of steam, cut-off B F making G, returning on C and admitting again on the line I, we have almost a perfectly theoretical diagram; but in the actual misuse and abuse of steam bounded by the dotted line, which is the indicator card, we have 219, the back pressure which should have been useful effect, and the little triangle bounded by the dotted line which is the induction pressure, or realized pressure after the steam valve gets open, the vertical line I and the irregular hypothenuse K L, we have an area of 26 on the planimeter, hence we have 219+194+26=439 as against 459 developed by the proper use of steam.

But there is another factor in the case: Using A in the third computation as our base line, triangulating with the dotted line E, which is the line of realized pressure in the cylinder, we obtain the line H as the volume of steam admitted at that pressure, and the expansion line should follow the lower line M, which strikes the theoretical curve G at N, and then follows so near that it is almost impossible to show the two lines on the card; this is supposed to exhaust freely, or what the engine should have done had the steam been entered at the pressure E, at the very commencement of the stroke, cut off at H, expanded on M G to the terminal pressure and exhausted freely. In this case we have 352.

By this time our readers may wish to know what all these letters, figures and lines mean, or where the working engineer is going to learn anything from such a mass of references. Let us see; in the first place we had a hundred pounds of steam, for the scale is 60, the engine was running 114 revolutions per minute, it made the dotted line diagram which figures 219; suppose we call it 219 horse-power, working against the back pressure 194. In other words, the boiler was yielding 413 horse-power to do 219. Steam was carried the whole length of the stroke after it was first admitted. If the steam had been admitted at the pressure represented by the line E, which is about sixty-three pounds, and been cut off at H E, expanded as shown by M

G, it would have produced 352 horse-power with an expense of a little less than half the steam, provided the valve had admitted the steam at the outset and the exhaust had not been checked. On the other hand, had this engine admitted the boiler pressure of one hundred pounds, cutting it off at F on B, properly expanded and exhausted, the steam which was in the boiler and was not used on account of defects in the construction of the engine, *a still less quantity of steam* would have given 459 horse-power as against 219 horse-power by this wretched misuse of the steam.

The valves in the engine from which this diagram was taken are very wrong in their construction, and have a fault common to many of the new engines of '83 and '84. They do not travel far or fast enough to give either induction free from the throttling, or eduction free from back pressure; steam cannot be used profitably or economically without free passage—into and out of the engine.

LESSON LI.

HARRIS-CORLISS ENGINE—DISTORTION OF DIAGRAM BY THE INDICATOR MOTION.

The approximate value of the correct reading of an indicator diagram is something which can be gained by careful attention to facts, and we believe only in that way. Fig. 110 is a rather peculiar case, from a Corliss engine 23×48, running sixty-six revolutions, seventy-nine pounds of steam at the moment of taking, nearly eight pounds of back pressure, and was the cause of considerable argument and investigation.

The line A is absolute vacuum, B atmospheric line of the instrument, C exhaust line of the indicator, D expansion line of the instrument, E realized boiler pressure in the cylinder, F boiler pressure. It will be seen that the engine takes steam very squarely, carries it for a short distance, and immediately commences to drop off. We have located the base line, G, a little beyond the center, in order to allow the steam time for settling down to its work. From the intersection A G we have drawn I E, and parallel to it H; the intersection of H E by this demonstration gives us the point at which steam was cut off, to give the pressure at G in the stroke. The demonstration is made for ascertaining whether the steam expanded correctly or not from the point E I; and the line J, which is dotted differently than the line D, is the hyperbolic curve from E I, or the amount of steam used. Curiously enough this line

J crosses the expansion line D at the point G, or very near it, and it falls nearly as much below the expansion line of the instrument on finishing the stroke, as it rises above it between H I and G H.

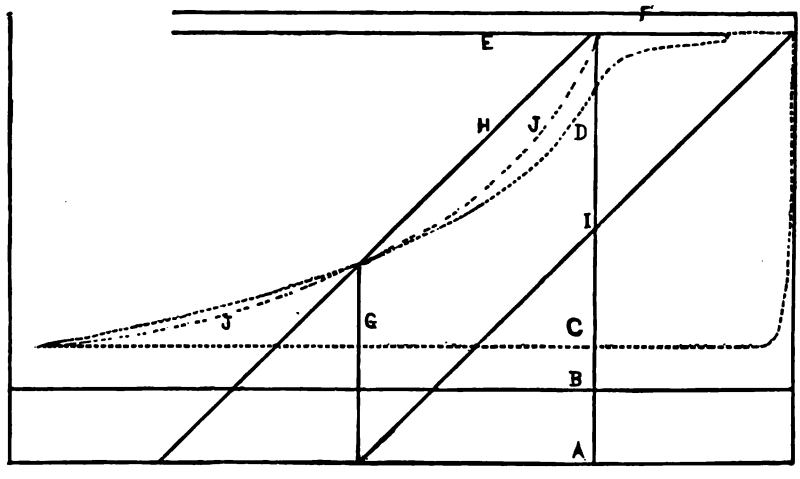


FIG. 110.

There is something rather curious about the peculiar formation of this line, as also in the cutting off, and after the question was submitted we wrote the engineer that his engine was either leaking or that his attachment was wrong, which gave motion to the indicator—a careful draft of all the connections settled the point that the motion was not square with the engine, and that the motion of the paper barrel of the indicator was so arranged that it ran too fast and too slow from distortion of the motion, and showed a "leaky valve" if the motion had been correct—but the trouble was remedied by throwing away a bad motion, and using the pantograph properly attached, and the distortion ceased.

LESSON LII.

A CURIOSITY—IN DIAGRAMS.

In Fig. 111 we have a rather knotty subject, more for the sake of the information it contains, but also to show the difference in indicator's performance. The diagram illustrated was taken from a Porter-Allen engine, one of a pair, right-hand engine, back end, boiler pressure eighty-two, fifty scale, revolutions 355 per minute, Tabor indicator.

The admission line A gets on very well until the piston of the engine commences to move, when an oscillation takes place, making a very attenuated-looking figure 8. Curiously enough, the first loop seems to be against the motion of the piston and the next one with it, as the steam is introduced, and the movement of the piston so sudden, carries the second slant of the pencil lever up above boiler pressure some twenty pounds; coming down again as the motion of the piston increases, crossing under B, making a most peculiar curve, dropping into the saw-tooth, and then upward by a reversed curve or a concave, instead of convex movement, turning over again, coming down in the direction of D; and, if you turn this wrong side up, you have a handsome Roman nose, rather sharp at the point, or a good-looking saw-tooth for a hand saw. The peculiarity of this, again, is a convex instead of a

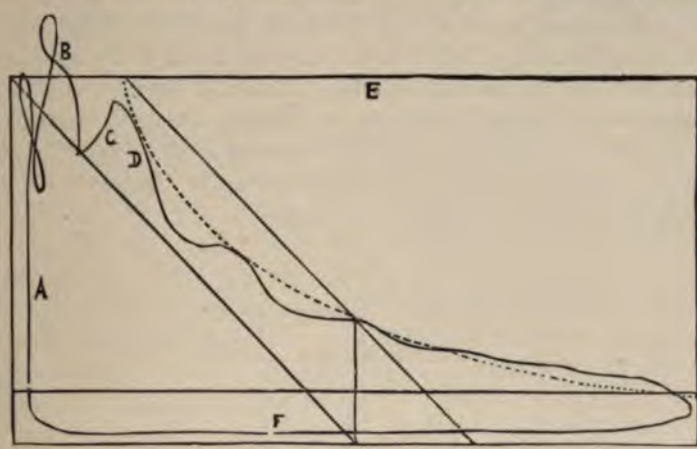


FIG. 111.

concave movement, dropping away considerably from the theoretical expansion line, which is dotted in. The vibrations, then, which take place in the expansion line, become less and less. but continue until the very end of expansion and commencement of release. The engine is working with a condenser, and the line F is that of the vacuum. We have erected, as nearly as possible, the theoretic point of cut-off from our own system of demonstration, charging a moderate amount of clearance; whether correct or not, we do not know. It will be seen that the demonstration gives us a close approximation to what would ordinarily be termed the visible point of cut-off, or where the expansion line really commences. The second notch comes closely up to the theoretical, the third the same, while the fourth, fifth and sixth are slightly above. Whether this is caused by any possible leak (which must be very trifling), or whether larger clearance would have made it still below, we cannot say, for in this case we have assumed the clearance, and, to our mind, it only shows that there is a certain analogy in the demonstration, and the actual effect wherever an approximation is made, and it also shows that the indicator, at high speed, may possibly become, in a measure, entirely unreliable in its

readings of the position of the valves—for in a case of this kind there is not the remotest approximation to any position from which we could work to adjust the valves. The impact of the steam entering the cylinder at the pressure and speed given, is something fearful—and the indicator may not have had a steady motion, and any irregularity, or instability, in the reducing motion would have given the distorted lines shown. The engine from which this was taken does not make any such diagram, and this is introduced as one of the curiosities of practice.

The question at issue really is: What made these funny-looking crooks and curves in this diagram? It certainly was not the engine. Was it the motion, or was it some defect in the instrument, or something between the instrument and the cylinder? Who can tell? This will be something for the engineers to work over, and it will well repay them for any trouble they may take. There are some curious features about it. This diagram was taken nearly two years ago, but it is just as well worth studying now as ever before, and, without further information, we cannot attribute all the fault to the indicator, or to the engine—but an insufficient spring in the indicator, or a tampering with the barrel-spring or a pendulum too weak for the speed and tension, either one will accomplish practically the same result—to a certain extent, but not to so radical a change.

LESSON LIII.

ADJUSTING CORLISS ENGINE VALVES.

This time we have an interesting illustration, and we hope our readers will not get confused with the several lines upon it. The diagram (Fig. 112) in this case represents an engine built by one of the best makers, and which had been abused most effectually. A shows the diagram in fine, dotted lines, after the adjustment was complete; B, a solid line, shows the second stage, or during valve adjustment; and C, a wavy line, shows where we found it. This is one of a series of diagrams taken to find out what power parties were using, with a view to ordering a larger engine. Commencing with the diagram C, and ninety-five pounds of steam, we obtain sixty-five pounds realized on the piston in the cylinder—a very bad beginning for a Corliss engine, but the engine was not to blame. Notice the two lines forming an angle at D; this is about where the line of admission would have come out if it had gone on at the same ratio, with the pressure at that point; but if the press-

ure had reached that point, it would have gone forward of D decidedly, owing to the quickening motion of the piston. Now, let us see. The steam valve does not open; the steam line looks like an old-fashioned poppet valve engine, which began to cut off the moment it was open. It is hard work telling where expansion begins or ends.

Having looked this matter over, and finding both ends were alike, we moved the eccentric a little more than half an inch ahead on the shaft, so as to quicken the *time* of movement. B was the result; the valve opens considerably quicker, and it will be noticed with this change we have eighty-eight pounds of steam. But by this time our crank valve is working nicely, but the head

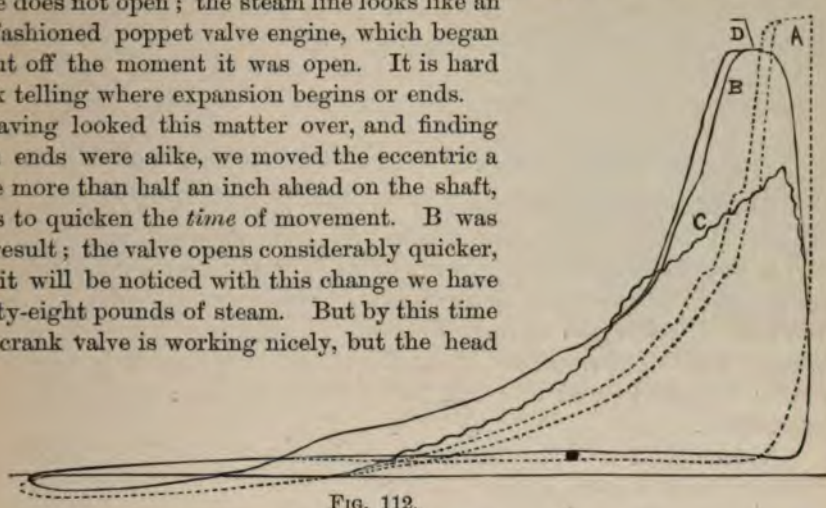


FIG. 112.

valve is pushed back by the jimcrank shaft, or, in other words, the claw pushes the valve back on its seat, so as to get a good hold and start again; but this wont do, so we must move the eccentric forward again, which is done, and we secure A, which is just about as well as we can do. We have now ninety-five pounds out of ninety-seven; take steam about at the right spot. Our crank valve at this time is a little too fast, so we must change that on the jimcrank by slowing.

We have not space here to make all the illustrations that would be necessary, especially as regards the release and compression. It will be seen, however, in the fine dotted line, that the compression and the opening valve merge into one line beautifully. The expansion line looks very nicely, but for the sake of avoiding any confusion we have omitted any demonstration, the object of this being to impress upon our readers the fact that the proper way to open the valve gives the best possible use of steam; and the reader who may be informing himself with the use of the indicator can see here a most notable case, where the exact opening of the valve gave a prompt cut-off, a beautiful expansion line to all appearances, exhausted slightly under the atmospheric line and compressed so as to make as fine a line as we need to work for. It is a simple lesson, but there is a good deal in it.

The whole thing was done in less than half an hour, and the engineer and the parties who were looking on, when they came to load the machine, never saw it do so well before. If an engine runs right with a light load, it will run well all the way through, and we have no doubt that this engine would have cleared itself creditably if it had been running and carrying steam as far as it could have done; but under these circumstances there would have been a good deal of loss, for the steam pipes were insufficient to carry any great part of the length of the stroke.

LESSON LIV.

EXPENSIVE "CUT-OFF" BY CHEAP ATTACHMENTS.

The diagram, Fig. 113, was sent us by an engineer with the request that we lay out for him the expansion curve from the apparent point of cut-off, and as nearly as possible from the cut-off made by the quantity of steam really in the cylinder, according to our method previously illustrated, the data of the size of the engine was not given and is immaterial for the purpose for which he asks information. The data which accompanies it is twenty-four spring, fifty-five pounds of steam in the boiler, head end of engine, seventy revolutions.

The diagram is a peculiar one, in fact a most wasteful one, and for that reason alone it is given space.

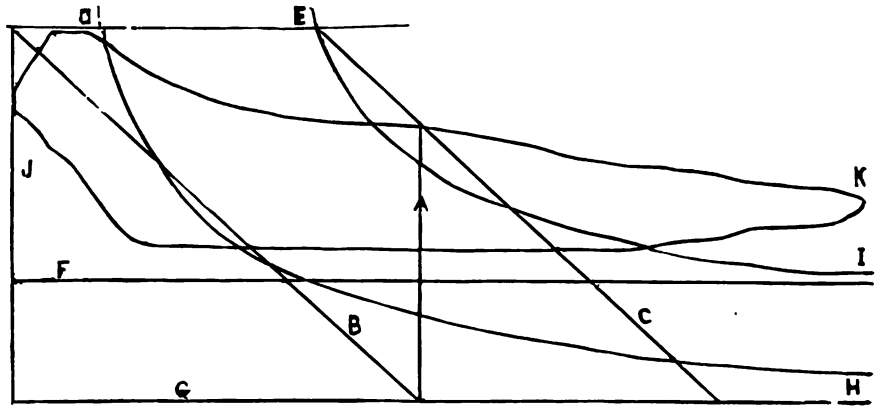


FIG. 113.

The line A is the basis of our computation of quantity of steam accounted for in the center of the expansion line. [The engine is supposed to be working with a cut-off]. B C parallel lines, B extending from the intersection of the vertical line and the line of initial pressure D E, E is the point of cut-off established according to this method of ordinate A, parallels B C, all of which are explained, in Lesson XLII, as the method of locating the exact point of cut-off, taking the expansion of steam somewhere nearest the center or the point of least variation. F is the atmospheric line of the instrument, G the line of absolute vacuum.

In answer to our inquirers we have taken the visible point of cut-off, D, slightly beyond the sharp corner, and, from the intersection of the line of absolute vacuum and the vertical line or admission line proper, have laid out

the theoretical curve according to the method referred to above. This line terminates at H and shows a decided change between the visible point of cut-off and the actual terminal lines, the point K in the actual diagram being twenty-seven pounds above the vacuum line and the point H being four pounds above vacuum line, and the point H is where the terminal pressure should be *if* D is the point of cut-off as it appears, and *if* the valves close tightly.

Taking the line A as the basis of our calculations, we find the point E to be designated as the cut-off by demonstration, a termination of the expansion line proper at I, being 1½ pounds above the atmospheric line of the instrument, 16½ pounds above absolute vacuum, while the real line of the instrument is, as before, twenty-seven pounds above absolute vacuum. There are some other peculiar features to this diagram; in the boiler we have fifty-five pounds steam pressure, only thirty-two of which at the outset is realized in the cylinder. If we follow the line of the instrument we find that after the valve commences to close, somewhere near D, there is a gradual sifting in of steam until it passes the intersection of the line A with the expansion line of the instrument; in other words, the engine takes steam a long way after the cut-off valve appears to be closed, and if there is any economy in the engine, it must be economy in running a cheap engine at an enormous expense for fuel. If the reader will figure the water consumption of this engine, for comparison with any size and speed engine he chooses, he will find it is enormous.

The exhaust of the engine is anything but good; starting with nine pounds of back pressure, averaging five, but perhaps this is not all in the engine, our informant does not give us this fact. Whatever may be in the engine it is not a good exhaust. The compression line is fair but the steam admission seems to be late, peculiarly so on the upper part of the line; the steam-carrying line, or the steam line proper, is very short, and while the visible point of cut-off is sharp to a certain extent, the practiced eye soon discerns that there is no expansion line to the diagram. It shows what is termed sifting in of steam, until considerably past the half stroke.

In outline the diagram has every appearance to us of a peculiar arrangement known as a regulating cut-off, where some sort of a cam is applied to the throttle-valve regulator, which lifts the throttle valve at the commencement of every stroke and drops it again. That probably accounts in the action of the regulator for the peculiar line from between the commencement of the admission line and the steam line. It is a sort of combination which is both unsatisfactory and expensive. The visible point of cut-off, as our writer terms it, at D, equals almost exactly one-ninth of the stroke; while the point of cut-off, supposing the valves were tight, or according to the quantity of steam used in the center of the expansion line, is shown at E, is 16-45 of the stroke or plus one-third; in other words the engine is actually using more than three times as much steam as is shown by the indicator diagram at a casual glance and without the application of some test to determine it. This is readily shown by the very great height of the termination of the expansion

line above absolute vacuum. The cutting off of thirty-two pounds of steam, where we should have fifty-five pounds, with a terminal pressure of twelve pounds above the atmospheric line, is eleven pounds too much at the termination of the expansion, and is just about in that ratio to the economical use of steam, as is shown in this case.

LESSON LV.

THE CORLISS OR MODERN COMPOUND HIGH DUTY PUMPING ENGINE.

Figs. 114 and 115 are from the Corliss Pumping Engine at Pawtucket, R. I. It has been running several years in charge of one of the most intelligent and painstaking of engineers, Mr. John H. Walker.

Fig. 114 is from the high-pressure cylinder, 15 inches in diameter, 30 inches stroke, making 47 revolutions per minute, scale 60, steam pressure 132 pounds, Corliss upright boilers being used, 130 pounds are realized on the piston and the steam line is carried as straight as is possible to the point of cut-off. The expansion line is a marvel of beauty and correctness; the release is early and the exhaust into the receiver shows a commencement of ten pounds receiver pressure and a terminal of eight pounds, there is very little rise in the pressure in this case. The admission could hardly be better. The demonstration in this case precludes the possibility of drawing the theoretical line a portion of the way, as the lines would pass one over the other. Very little compression is used; that, for some reason unknown to us, is one of Mr. Corliss' ideas, to work with little or no compression. There is a very slight difference between the apparent cut-off and the theoretical, but it is so exceedingly slight as to be almost unworthy of notice from a critical standpoint.

115 is from the low-pressure cylinder of the same engine, the cylinder being 30 inches in diameter, 30 inches stroke, running 47 revolutions per minute, scale 12. 114 is from the front end of the high-pressure cylinder, and 115 from the back end of the low-pressure cylinder. From the ten pounds in the receiver, we have nine pounds initial pressure, gradually falling off to seven pounds before the close of the valve, expanding to seven and one-half pounds below the atmospheric line. The condenser takes hold at twelve and one-half pounds, the maximum vacuum being about thirteen and one-half pounds, or very nearly approximating to the theoretical. The demonstration

in this case shows a very close approximation of the actual to the theoretical, taking into account the lowest pressure from the initial and the point of cut-off.

This engine has been running some eight years, and these diagrams were selected from the regular indication of each day. Comparing the two diagrams one with the other, the high-pressure gives about the highest possible effect of steam, and the low-pressure gives almost the maximum efficiency of the receiver pressure for the distance which it is carried. We have, therefore, a very fine result economically, and through the courtesy of the engineer we are furnished with the following facts from his regular log-book, which has been carefully kept every day since the engine was delivered to the Water Board. This engine was originally built to supply the town of Pawtucket; since that time they have added a very large mileage of pipe and a large amount of water to the supply, so that the pumping engine is now furnishing double what it was originally intended to do, and this over a very scattered area of territory. The engine is now running, November, 1884, twenty-four hours per day, the actual amount of coal consumed is 216 pounds per hour; Wilkesbarre egg coal is used, which costs $4.35 per ton of 2,000 pounds, screened; the amount of ashes is nearly twelve per cent. and when we say 216 pounds of coal per hour, this is the actual amount of coal fed into the furnace, no allowance being made for anything. The pumps of this engine are now working under a head of 272 feet. The high-pressure diagram figures 72.658 horse-power, the condensing cylinder figures 65.398 horse-power, making 138.056; the variation between the two ends is very trifling. Taking the coal which is actually consumed we have 1.57 pounds per horse-power per hour; taking the combustible we have 1.39+ pounds per hour, per horse-power. Taking the cost of the power in dollars and cents, calling all coal, we have 3.4 mills per horse-power per hour, while if we figure the combustible, we have the cost of one horse-power, per hour as 3.02 mills.

The duty under the Board of Experts' test, was 133,522,060 foot-pounds for one hundred pounds of coal. Mr. Corliss took exception to this, and denominated it the "humbug" test from the fact that allowances were made. An absolute test made afterwards by the same Board on Mr. Corliss' basis gave it a duty of 104,357,654 foot-pounds per hundred pounds of coal, and this duty has been somewhat exceeded in its regular every-day work, while in charge of its efficient chief. The duty from the time of its start, January 31st, 1878, to the 6th of November, 1878, was on fuel consumed to pump, 106,234,300 foot-pounds. In June 1882, the engine was stopped for inspection and the piston rod in the low-pressure cylinder, where it passes through the plunger in the pump, was found to be so corroded by the action of water, that it was necessary to have a new piston-rod. This was the first repair made upon the engine. The duty of the engine for the twelve months ending January 1st, 1883, was 113,439,331 pounds of water raised one foot high with a hundred pounds of coal, counting all coal used with no deduction for ash or cinders.

It has been a most gratifying success, both in economy, durability, lack of repair bills; and the diagrams show if not the highest, certainly a very high, economy considered from any point, taking advantage of no technicalities, allowances or possibilities. These diagrams may be studied critically, in comparison with those in some of the preceding lessons, where compound engines of foreign builders are compared, and with favor to Mr. Corliss, upon grounds of absolute fact, with no assumed allowances of any kind.

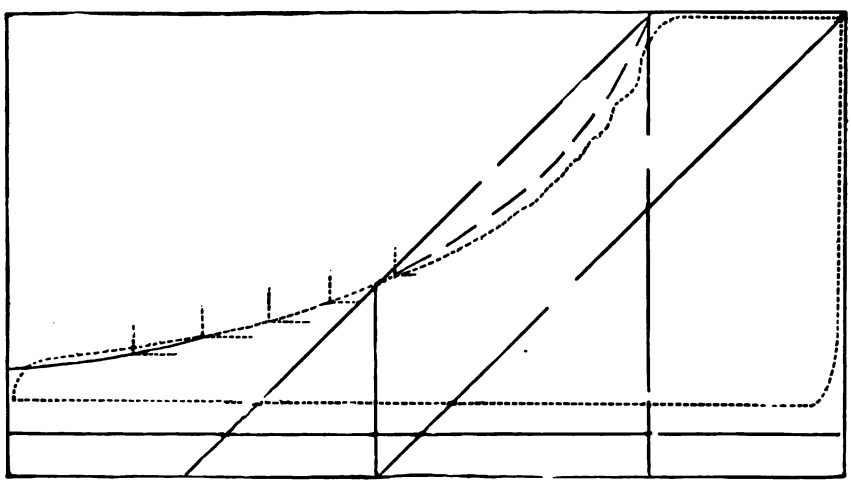


FIG. 114.

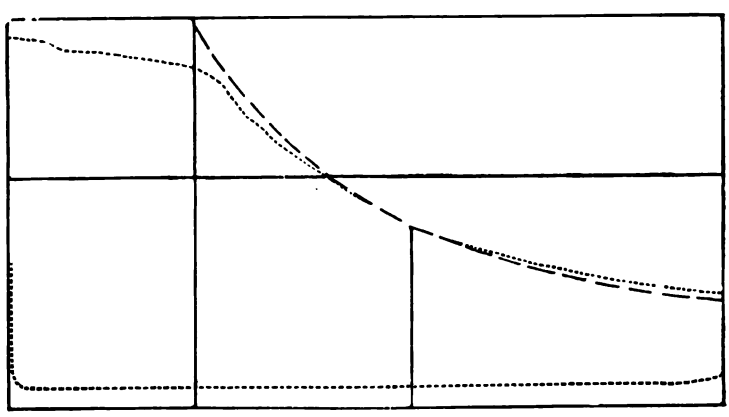


FIG. 115.

LESSON LVI.

SHORT CONNECTIONS TO THE ENGINE, WITH NO CHANGE OF POSITION FROM THE THREE-WAY COCK ATTACHMENT IN FIG. 117.

Diagram Fig. 116 is one which is somewhat peculiar in respect to an excessive cushion. It is taken from one of the new Buckeye engines, running 222 revolutions per minute, with a steam pressure at the moment of 92 pounds, scale 50, Thompson improved indicator.

In justice to the engine we will say, the party in charge was partial to the three-way cock for indicating, and Fig. 116 was taken from the same engine, with not the least change of valves from Fig. 117. Let the reader compare the two outlines.

In this case, A equals the vacuum line, B the atmospheric line, C boiler pressure at the moment of taking, D highest pressure by compression, E point at which the exhaust valve closed on the return stroke. In this case, the exhaust valve closed at about 3½ inches before the end of the travel, and

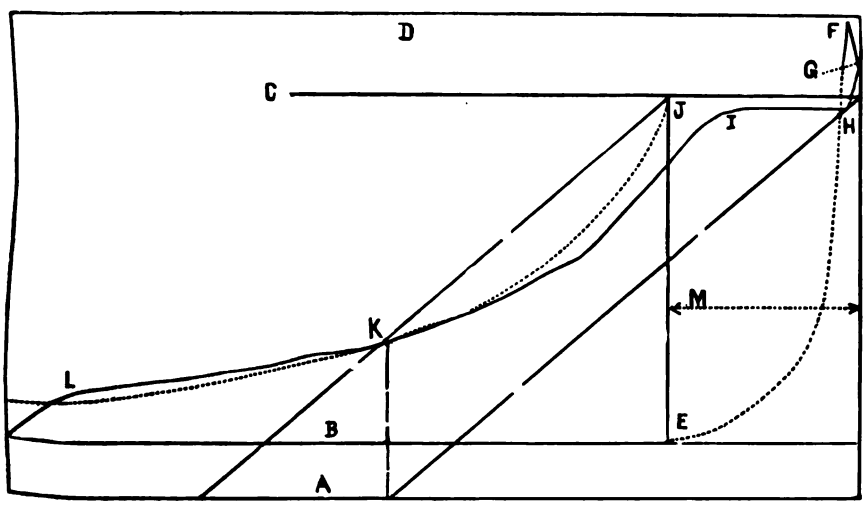


FIG. 116.

although the engine was exhausting very freely, in fact, without any perceptible back pressure on the indicator, it will be seen that at the point F, a little more than a quarter inch from the end of the stroke, the compression amounted to 113 pounds. From F, the rest of the stroke, there appears to have been a slight leak, a portion of which was undoubtedly in the indicator, and some of it may have been in the piston or valves of the engine, so that from the point F the pressure falls away to the angle indicated by the dotted

line G. From this angle it will be noticed that the pressure continues to fall, while the engine had passed the center and the indicator had commenced to move again in the direction of the outward stroke; G indicates the point at which the crank passed the exact center of the return stroke, and commenced its outward stroke; meanwhile the steam pressure slightly drops until H is reached, which give us between 87 and 88 pounds initial; from H to I the steam is carried, and at I the steam valve commences to close.

The peculiar angle formed by the line dropping from its highest point, F, is caused by a fall of pressure while the engine completes the last portion of the stroke, the angle in the line F, H, shows the precise point where the motion of the engine changes, and after the motion has changed the pressure still continues to fall, showing that the valves of the engine were in a splendid condition and were tight. At H we have the first real evidence of the steam valves opening, and the steam line crosses the compression line, making the steam line H I. Here we have another most interesting example of the efficiency of the indicator when correctly applied, and its lines correctly read from the diagram. In many cases such a compression line would be at once called an early admission line or "taking steam too quick"—but such is not the case.

Now, to analyze the diagram for efficiency, we will commence our demonstrations by the line K, the actual pressure at K gives us an absolute cutting off of the pressure of steam realized at C, J, so that while the valve commences to close at I, apparently it becomes closed at J, or very nearly so; from J to K the theoretical curve runs slightly above or outside of the actual curve of the instrument; from K to L, the point of commencement of release, the theoretical line runs slightly under the actual line of the instrument. The release is most excellent, and it commenced under about twelve pounds pressure, making a very clear exhaust and commencing to compress or cushion too early and making the loop. The particular feature of this loop is a very considerable shock to the engine; in fact, there is quite too much compression, and if the engineer will reduce this compression by one-half, his engine will sail over the center much easier, and without so much wear and tear on the connections, brasses, etc, The boiler pressure in this case is very handsomely realized, showing that the makers of the engine have made considerable improvement in proportion and motion of their valves.

Taken all in all, the admission and expansion, release and exhaust lines of the diagram are excellent, the compression is no fault of the design or mechanical part of the engine, if the compression is reduced to less than one-half the amount shown here. The engine will do more work with the same steam, and will regulate better without any doubt. It is not policy to compress twenty pounds above the initial pressure you are working with; it does not make the valves last any longer, or work any easier; it causes entirely too much strain on the brasses and connections, and is bad policy every way. The dotted line M, from the line J to the vertical line at the end of the diagram, gives the volume of the cylinder filled with steam, simply for the purpose of computation.

This lesson is a most complete demonstration of the lack of reliability of the three-way cock attachment, when used to *adjust* the valves. Fig. 116 was taken, close connection, on each end of the cylinder, only one end shown.

LESSON LVII.

THREE-WAY CONNECTIONS FROM SAME ENGINE AS LESSON LVI.

The old way of side pipe and three-way cock still exists. It is entirely useless for adjustment of valves or for any other than approximation to power, position of valves, or realized pressure.

The reader will find food for thought in carefully comparing diagrams, Figs. 116 and 117, with each other—both were taken from the same engine, with no sort of change except the side pipe and three-way cock were used in Fig. 117 and taken off in 116, the spring of indicator being changed to suit the increased boiler pressure in 116.

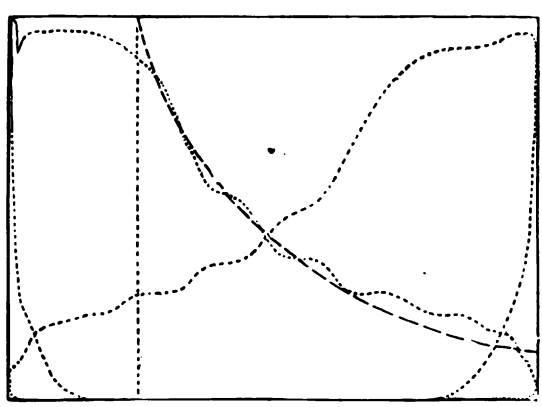


FIG. 117.

Figure 117 was taken from a Buckeye engine, made by the Buckeye Engine Company of Salem, Ohio, nine inches diameter of cylinder, fourteen inches stroke, 225 revolutions by the counter, eighty-five pounds of steam in the boiler, throttle valve wide open, scale of spring, forty, Thompson improved indicator. This engine was on exhibition at the American Institute Fair, New York, and is one of the Buckeye Improved. The makers have for

the past year been making changes, with a view of improving the economy, the regulation and the action of their engine.

The engine was running electric lights, and this will plainly tell of any trouble in regulation. The diagram 117 was taken upon one of our own indicators, but it has just this defect, it was taken by a three-way cock in the center of the cylinder, a thing which we disapprove of, from the fact that it introduces inaccuracies. The steam had entirely too much water in it, but that should not be taken into account against the engine.

The application of the theoretical curve to the diagram shows a very good action indeed of the valve, and we have taken the highest pressure realized at the moment of impact, and it will be noticed that the theoretical curve follows down past the center of the stroke, almost on the actual line of the instrument. Below the center or half-stroke, as the motion is changed from fast to slow, the actual line of the instrument rises somewhat above the theoretical. This may be caused by the change in the pressure and the amount of water present; it probably is not any fault of the valves. The action of the valves on this engine is certainly very good. It is one of the best Buckeye engine diagrams we ever saw, and if the improvements are up to this quality of work, the engine will do better work than ever before, and give the best results.

We have only made the theoretical curve upon one of the cards. There are several points in it to study, particularly the action of the steam valve in taking steam, the difference in compression as between the two ends. This short diagram was made use of because we refused to take a diagram from another instrument of greater length, which does not show the oscillations in the expansion line, and makes quite a difference as between the compression shown by the Thompson. We would call especial attention to the serrations or fluctuations in the expansion line, which show the most delicate action of the indicator—and the variations caused by rapid expansion and changes of temperature, pressure, etc.

These diagrams bear close examination, and are a very close approximation to the theoretical expansion, bearing in mind that the position of the valves and their action as to motion are erroneously shown by that attachment, which should be prohibited everywhere—a three-way cock and long side pipe. [See lesson LVI in connection with LVII.]

LESSON LVIII.

HIGH COST—LOW ECONOMY STEAM YACHT COMPOUNDS.

Fig. 118, H. P., 119, L. P., are a pair of diagrams from one of the rich men's fancy yachts, more expensive than fast. 118 is the high-pressure diagram which

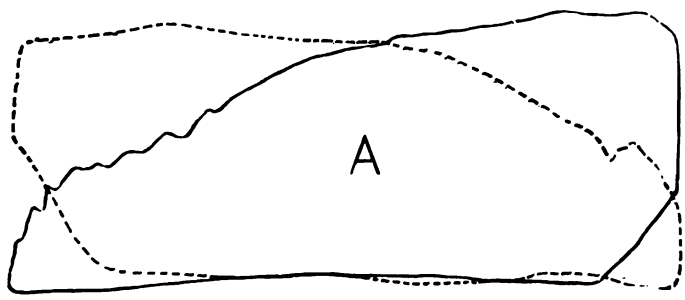


FIG. 118.

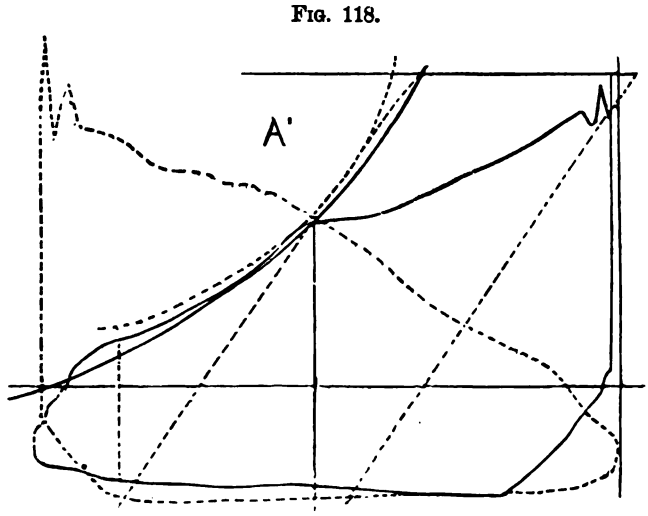


FIG. 119.

came to us without any atmospheric line; 119 is the low-pressure diagram; the scale of the high-pressure being fifty to the inch. We have assumed the dotted line as atmospheric line in Fig. 118, at slightly an excess of the realized pressure on the low-pressure diagram, which is sixteen per inch. We have

twenty-six pounds realized pressure on the low-pressure cylinders; on the high-pressure cylinders we have made no demonstration, from the very fact that we are not certain of our data, and at the best they are as wretched diagrams as were ever taken from anything in the shape of a steam engine. Those who are interested will understand that a link motion is used, but it must be a sorry link which makes such a use of steam as is shown in the steam line of the solid-drawn diagram. In Fig. 118 the admission line commenced very well, but when the steam line begins it is a curious line; really there is no cut-off to it, the expansion line is a fearful one, and not economical or correct, and is convex instead of concave, and when it comes down toward the release, the line instead of being an expansion is turned into saw-teeth. Like most compound engines, the exhaust line is considerably higher in the center than at the commencement. This is all natural enough, but when we turn to the dotted line on Fig. 118, we have, if anything, a worse line than the solid line in the diagram; a peculiar jump about the commencement of release we are unable to account for satisfactorily to ourselves, but which is probably caused by low-pressure cylinder valves.

If the party who took the diagrams had been careful to draw in his atmospheric line, we should have been pleased to make a demonstration. We have drawn in the atmospheric line at about what we supposed it should be drawn, and this gives us full initial pressure 105 pounds, as the throttle valve is wide open, and the link full, scale fifty. On the low-pressure card we have something more to work by, for in this case the atmospheric line is properly drawn in by the instrument, scale sixteen, link up full, speed in both cases 126, wide open. Here we have an impact initial pressure of twenty-six pounds, a vacuum of about nine pounds. The cut-off is very well defined in the solid line and less so in the dotted. We have made two demonstrations here, one with the dotted line and the other with the solid line. The dotted line is to ascertain whether the steam expands under the generally conceded theoretical law after expansion apparently commences. The solid line shows what ought to have been done at the actual pressure at the point of cut-off which is visible. We start with a pressure of twenty-three pounds; at a little past half stroke it runs down to 13½, and the diagram line of the indicator shows that the valve closes. The dotted line shows that the valves were practically tight, for the pressure falls away triflingly, if we take the commencement of release, or just prior to that point, as the basis of that computation. But if we take the actual pressure before the valve becomes positively closed on the line, we find that the general ratio of expansion is closely on the theoretical, understanding always that there will be more variation in the link motion than in the positive eccentric and lever or rock or wiper motion. Now, if we use our sixteen scale as a rule, we find the solid line from which our demonstration is made to be twenty-five inches (call it) from the commencement of the stroke. At this point 13½ pounds of steam were cut off, having been reduced in pressure from twenty-three, and carried, we will say, twenty-five inches. Now if the pressure had been realized it would have required only eighteen inches, cut off at twenty-three pounds, or, in other words, it would have required

18-25, or two-thirds, practically, the amount of steam it did require. The high-pressure diagram is abominable, and the use of steam is without any sort of economy, the pressure drops rapidly both on high and low-pressure cylinders after the valve gets open. In the low-pressure cylinder there may be some excuse from lack of volume, or pressure varying in receiver, but in the high-pressure cylinder it is choked or wiredrawn by insufficient ports or pipes.

These engines were built in 1883. It is, perhaps, needless to say that this is not the fastest yacht in the world by any means, and whoever the builder may be, he need not consider himself particularly flattered with this kind of result, if economy is to be considered at all.

LESSON LIX.

ANOTHER OCEAN S. S. COMPOUND ENGINE.

We hear so much of the economy of some of the new ocean steamships that it will do us much good, perhaps, to examine some of the results of the work of the engines, and for that reason diagrams, Figs. 120 and 121, from the high and low-pressure cylinders of a compound engine are introduced; the high-pressure cylinders of which are seventy-two inches diameter, sixty-six inches stroke, fifty-four revolutions, seventy pounds boiler pressure, scale thirty-two. The same letters apply to the same lines on each for comparison. On the high-pressure diagram steam is cut off at about 18-49 of the stroke. Starting with a boiler pressure of seventy pounds, E, and do not get within seven pounds of it on the piston. There is very little approach to an expansion line, and no one can tell where the valve closes from the appearance of the line. In fact, there is no marked feature of it to show where any expansion takes place.

The steamer in question has been built several years, and is not by any means the fastest or the most economical now afloat; she was built to accomplish a certain purpose and has done it, but she has never been economical with fuel to the extent that some of the more modern compound engines have been except by remote approach.

Making *a* the base of our computation, give us B, E, point of cut-off and volume, reference letters the same in both diagrams. From B, the pressure given at *a*, the line F shows us what power should have been exerted and where the steam should, under ordinary conditions, have been cut off and expanded

to. It will be seen that the boiler pressure is not realized, cut-off is entirely lacking in definiteness, and the end of the expansion is considerably above that point which the actual pressure at *a* gives from the cut-off B, E, showing clearly that there is either a very radical error in the indicator motion, which is hardly probable, or if we look at the low-pressure cylinder, or that the valve is slow in closing, or that the valve leaks, which is the most probable reason of all, for we are certain that the valve closes slowly—from the course of the line. The high-pressure cylinder exhausts under a pressure of about eleven pounds to start, at the center it is fifteen, and at the commencement of compression it is almost fourteen. The admission line is a little late in the opening of the valve, and the rounding over at the corner is not of necessity due to the link motion which was used, but rather to some little give or play, or what is usually termed lost motion. We cannot consider this as a very economical diagram, there is too much loss in realizing the boiler pressure, and a wire-drawing of the steam, (if tight valves) and the exhaust of high-pressure cylinder into receiver is fully as high as it should be, and much higher than the low-pressure utilizes. The expansion line is not nearly as good on the high as the low-pressure cylinder.

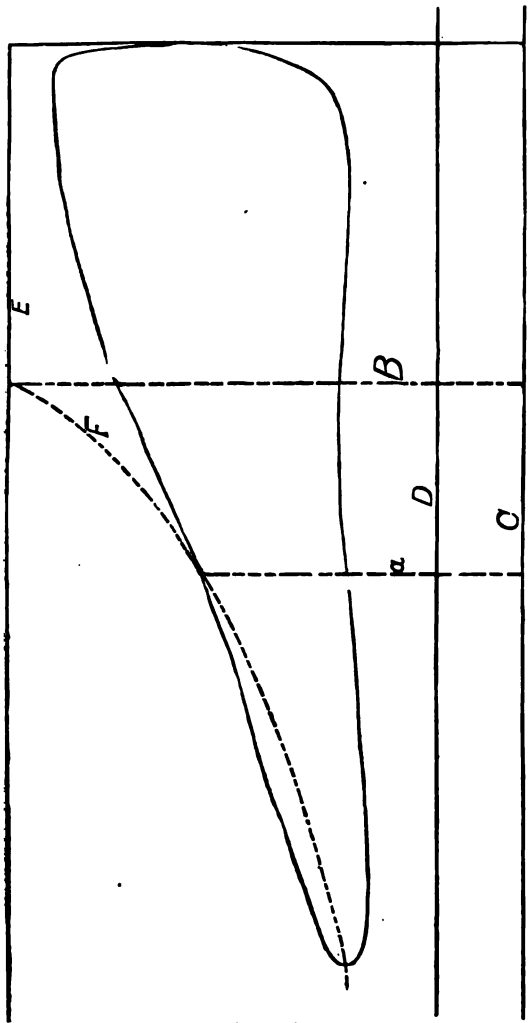


Fig. 120.

Taking the low-pressure card made at the same time, E representing the initial pressure from the high-pressure cylinder or receiver, *a* the base line, gives us B as the volume of cylinder at which the valve should have closed to have made the pressure at *a*, and in this case we have a tighter valve and a very much better condition of circumstances, showing but exceedingly trifling variation as between the theoretical and actual, taking the pressure at *a* from

which to make our demonstration. In this case the pressure is a variable quantity, changing from one to the other cylinder in exhausting and the acceleration of speed of the piston, as well as in condensation, which may take place in the passage or in the receiver, so that we lose somewhat in the low-pressure cylinder from what should be the initial pressure if we had received the whole eleven pounds from the exhaust of the high-pressure cylinder, passing through the ports and into the low-pressure cylinder. We, therefore, get only nine pounds realized, and lose again before cutting off about four pounds more, expanding below the atmospheric line; in this case we have ten pounds vacuum in the condenser to start with, and this is held very well until more than two-thirds of the stroke has been made.

Here is an answer to those people "who do not believe any cushion can be obtained in the low-pressure cylinder;" if not, then what makes the compression in this diagram? It commences to compress at about 7–45 of the stroke, say one-sixth. The admission line is very square, and the admission

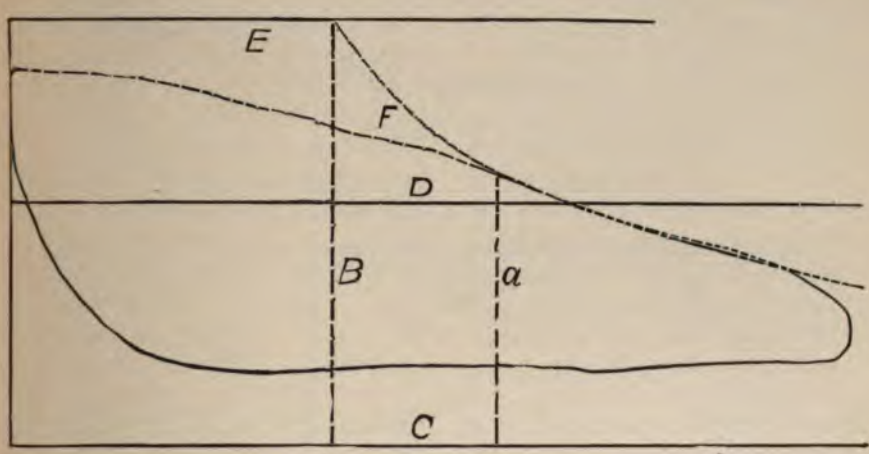


FIG. 121.

and carrying of steam in the lower-pressure cylinder is better than it is into the high-pressure. The expansion line and the theoretical line very nearly coincide through the major part of the distance from pressure at base line *a*, showing conclusively that the valves in this case do not leak and that the difference in the high-pressure diagram (probably taken by the same motion) cannot be in the motion but is in the valve. A decided falling off from pressure that under the circumstances should hardly be allowable, and about two-thirds the vacuum that should be realized is obtained.

We do not know the precise percentage of coal this steamer is now burning, but it was very largely in excess of some of the later steamers at the last time we knew of it. The lower-pressure cylinder is 120 inches in diameter, sixty-six inches stroke, fifty-four revolutions per minute, scale twelve, pressure variable. It may interest some of our readers to figure the power in these diagrams from the data given. The low-pressure cylinder

cuts off at about 17–45 of the stroke, starting with an initial pressure of nine pounds, cutting off at a pressure of a trifle over 4½ pounds; the commencement of release is four pounds under the atmospheric line, which shows a very good grade of expansion. But we must not expect perfection in these large engines, although we might probably attain higher results of duty than these particular diagrams show. The principles of adoption are the same—economy, speed, etc.,—as with the stationary engines. There is plenty of data here to figure from, and it would be interesting, for those who care to take the trouble, to solve the points of ratio of expansion, the amount of water, power, etc.

LESSON LX.

AN EXPERIMENT BY AN ENGINE BUILDER.

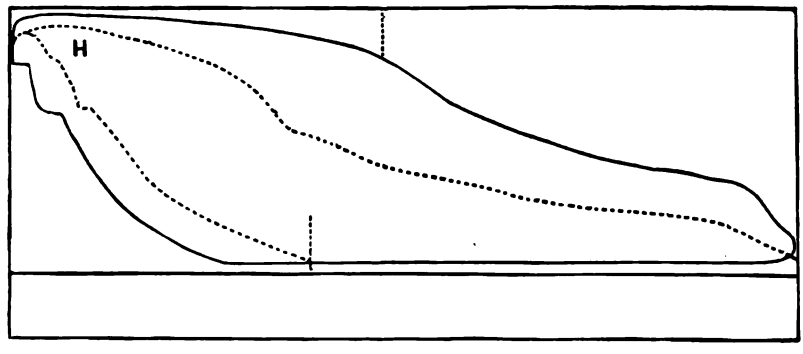


FIG. 122.

Fig. 122 is from the first engine of a new builder for the especial purpose of electric lighting. The data is: Boiler pressure 70, spring 40, diameter 10⅜, stroke 12 inches, revolutions 115.

To attempt to demonstrate all the faults in this engine would be to do work which should have been done by its designer and builder; for this we have neither the space nor the disposition. This is evidently a very bad imitation of a well-known engine. Taking initial pressure, seventy pounds boiler pressure; to economize room we have traced the dotted line card, showing the same engine under a little different load. We have fifty-six pounds

initial pressure out of seventy. This in itself will condemn the engine, providing the connections are free. The engine starts off with a round instead of a square corner between the admission line and the steam line. With an initial pressure of fifty-one pounds, gradually rising to almost fifty-five, and at about the point where the cut-off appears to take place, we find between forty-five and forty-six pounds of pressure, having fallen off ten pounds in carrying steam four-tenths of the stroke. The engine commences to release with a pressure of seventeen pounds on the piston, releases very well, but does not get down in the exhaust to the atmospheric line; compression starts at rather more than half the distance that the steam is carried. The compression line here may have been shaken up by a poor foundation, but more probably by a constant changing of pressure in the compression in the solid line card, but in the dotted line the compression line is a very queer one, and the little hook at the extreme end, with the peculiar formation of the steam line, in starting on to take steam for the stroke, shows that the valve does not open as wide with a light load as with a heavy one. Notice that the steam is cut off at a very much lower pressure in the light load, proportionately, than the full load, on the larger diagram of the two. Whatever makes the funny jog in the dotted line on the expansion line after cut-off, or whether the steam is carried to that point of the indentation and then the cut-off actually takes place, we are a little at a loss to tell from the appearance, and the card has no value in an economical way.

The diagram is very uneven, and contains so many faults that we have not cared to give the time to a demonstration on the expansion curve. This engine would be most decidedly lacking in economy; whatever its regulation may be we do not know, but it was evidently built by some man who has not progressed into the new style of valve motion, for the valves do not travel correctly nor far enough. Whatever their proportions of ports may be we do not know; one thing is sure, it is too small, either by insufficient opening of the valve by the action of the regulator, or by insufficient ports and passages. Such a diagram may do fairly at 115 revolutions per minute; what would it do at 250 or 275, the usual speed of the engine of which this motion is evidently a copy?

LESSON LXI.

EFFECT OF SPEED ON REALIZED PRESSURE IN THE CYLINDER—A LESSON ON FEED PIPES.

In Figs. 123, 124, we have valuable information in reference to one of the most important, least-attended to details of steam engineering. Both these diagrams are taken from the same engine, under the same conditions, except with reference to speed. Fig. 123 is from the engine in its regular work. Cylinder diameter 34 inches, stroke 60 inches, revolutions 50 per minute, boiler pressure 69, scale 40, condensing. We find 62 pounds of initial pressure realized. By the demonstration, with A as the base line, we find the cut-off at D, C. The theoretical curve, it will be seen, follows the expansion line exactly, covering it from a short distance beyond the line D, which is quite sufficient for the purpose of demonstration, showing that the 62 pounds steam

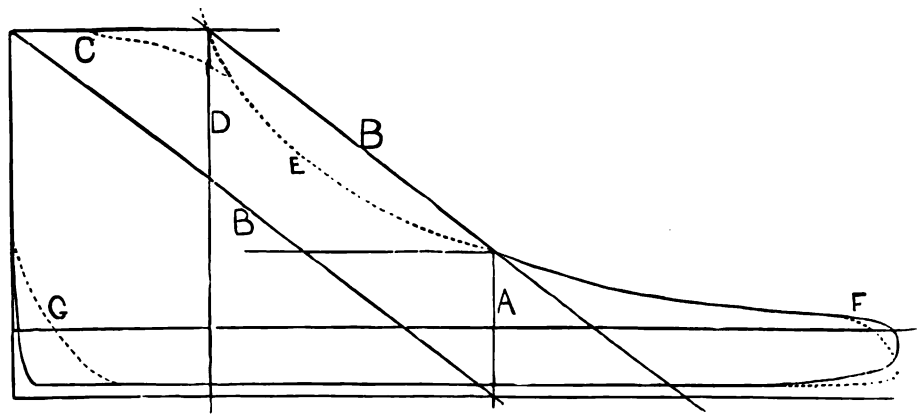


FIG. 123.

pressure cut-off at D, would make precisely the expansion line, making a most effective working of the steam; and for determination of the one point of particular interest in this lesson, viz., that the feed pipe in this case was amply sufficient to supply that engine at that speed, doing that amount of work. In our own practice we would prefer to have had the exhaust valve open sooner, as at F, in order to allow the condenser to sooner realize the vacuum. In this case, on the opening of the valve, about four pounds is realized, while, were the valve opened slightly earlier, ten pounds ought to have been. If the exhaust valve opened sooner, it would necessarily close sooner, and we should have an approximation of the compression line to that of G.

In Fig. 124 we have the same engine running 68 revolutions per minute for some especial work required; at the time of taking the diagram, we have 73 pounds of boiler pressure. In this diagram, 124, it will be noticed that the admission line is a trifle late, the initial pressure realized is 72 on the very commencement of the stroke, or before the piston gets into motion; directly the motion of the piston commences to increase, the pressure falls away very rapidly, so that at the point of cut-off we have only 58 pounds. The demonstration in this case shows that the pressure falls very rapidly indeed, from the commencement of the movement of the piston until at the point where the theoretical curve and the actual line of the indicator touch, just above the letter D; there was 20 pounds less realized pressure than at the commencement of the stroke, leaving 52 pounds effective pressure on the piston only.

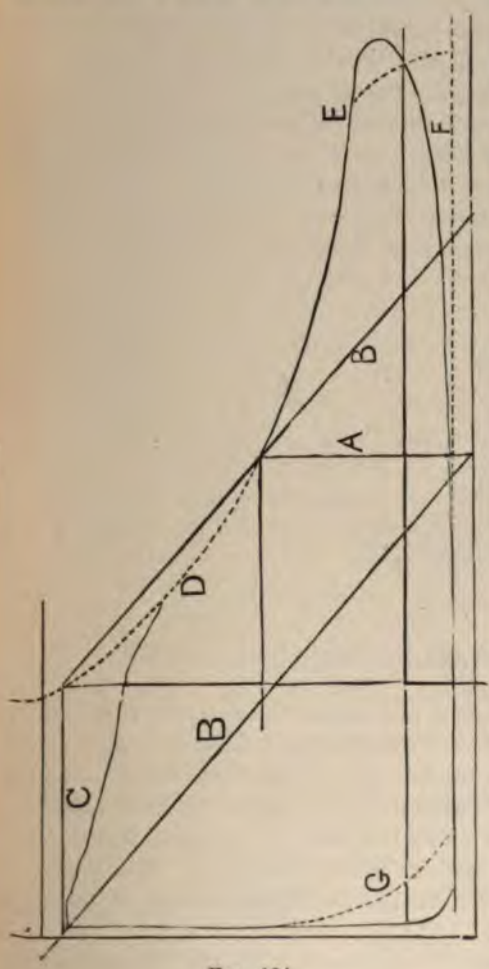


Fig. 124.

The demonstration in this case, made from the point A, gives the cut-off on the line C, from which the theoretical curve is dropped, exactly following the line of expansion from the intersection of the two lines to the point which is the base of the demonstration. Upon continuing this line, the terminal pressure will be found slightly above, showing that a volume of steam, equivalent to the full pressure, on the line C up to the line between B, D, was used to effect this. In the case of this movement, we find that the supply pipe for this engine, which was sufficient for 50 revolutions, is entirely insufficient for 68 revolutions; and we also find another feature at the terminal of the expansion line, viz., that a very much less vacuum is obtained, and none at all until after the piston has returned several inches on its stroke. The maximum vacuum is ten pounds; the first quarter of the stroke eight pounds only is realized; the second quarter nine, the third quarter ten, and the cushion commences on ten pounds. Had the exhaust valve been timed earlier, as recommended for 123, we should

have obtained the dotted line E or some approximation to it, and the dotted line F, as a realized vacuum, which would have added materially to the power of the engine and also in the saving of steam. Allowing the alteration to have been made in the time of the exhaust valve, we should also have obtained the compression line G and have compressed to 35 pounds, saving exactly this amount of live steam in opening our steam valve upon 35 pounds instead of nothing. This shows the necessity of a proper supply, and that the supply pipe must be proportioned to the speed at which the engine will travel, and that unless this is done some such change in matters will occur as that shown. Should 123 call for a much larger load, the supply pipe in that case would be insufficient, for it must be understood that after the piston goes a proportion of the stroke in its travel, it calls for steam very much faster than when it first starts. In this case, 123, the pressure is somewhat reduced, and if the engine were required to carry three or four inches further we should probably find, in a less degree, the same features attending the steam line as in 124.

LESSON LXII.

ANOTHER LESSON ON SUPPLY PIPES.

Changing the circumstances as much as possible to make the application more forcible, we have taken Fig. 125 of the high-speed class of engines and running under fully as much load as the builders recommend. This is taken from an Armington & Sims, 14½ inches diameter of cylinder, 13 inches stroke, running 245 revolutions per minute, boiler pressure 92 pounds, scale 60, indicating about 125 horse-power, fed with a six-inch steam pipe. The realized pressure is 83 pounds, the steam is carried 150 feet from the boilers through several elbows.

The demonstration in this case by the line A, parallels B B, gives the point of cut-off at B C (for clearness the ordinate is not drawn), C represents the steam line, its cut-off is very sharp. The oscillations in this diagram are referred to in previous lessons, and the point of cut-off and the following of the theoretical curve is through the intersecting points of the lines *d d* which are drawn at six different places in the expansion line. It will be seen in this case, that the variations in the line of expansion of the instrument vary but very slightly from the actual passage of the theoretical line, and this approximation is so close that the drawing of the theoretical curve would simply con-

fuse. The commencement of release at the point E compares well with the compression F, but if anything the compression is slightly larger in proportion to the stroke than the release, and in a high speed engine this is somewhat a necessity. The exhaust line varies only in the least possible degree from the atmospheric line of the instrument until the exhaust valve closes at F. The compression line has the same wavy appearance that the expansion line has, but exactly reversed in effect. We have a compression here amounting to 60 pounds when the steam valve opens and the admission line is formed.

The amount of power yielded by this engine is large, when we take the volume of the cylinder into consideration, but is not its maximum power when we take its speed into consideration. The admission and steam lines are very square; the cut-off is very clearly marked and all the lines of the diagram give a high efficiency, which has since been proved by trial of the engine, and in comparison with Figs. 123 and 124, it will be seen that a very large pipe for the volume of the cylinder is required as the speed is increased. The efficiency of Fig. 125 is above 90 per cent. and shows good sense in connections, as the outline, in itself, shows very satisfactory work with the steam so far as valves and engine are concerned. It is probably in three cases out of five that we find too small feed pipe, and in entirely too many cases too small exhaust pipes as well. Both of these points work against the efficiency of the engine and whenever efficiency is involved then economy is certainly less than it should be. The comparison between the three diagrams 123, 124, 125 will be interesting on this point of feed pipes, realized or lack of realized pressure.

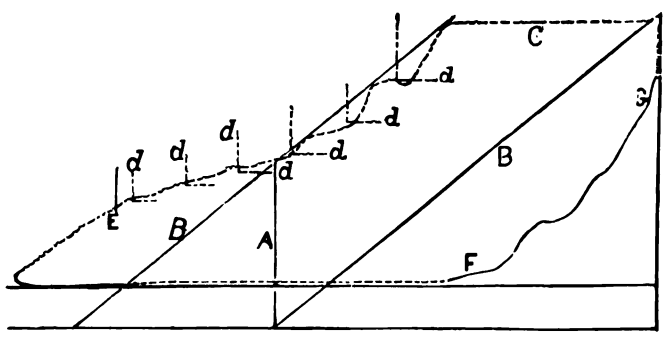


FIG. 125.

LESSON LXIII.

LARGE CYLINDER, LOW-PRESSURE ENGINE ON A SOUND STEAMER.

Fig. 126 was taken from the steamer Providence, one of the Old Colony Steamboat Company's Sound steamers, running between New York, Newport and Fall River. The cylinder is 110 inches in diameter, 12 feet stroke, and, when running full, makes 17 revolutions per minute, scale 16, steam at the moment of taking, 23 pounds.

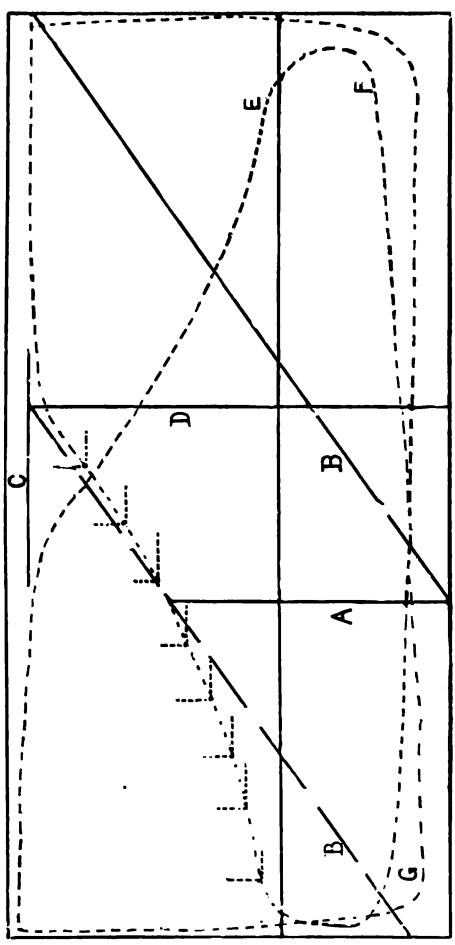


Fig. 126.

The demonstration has been made only upon one diagram. The admission line is a little late upon the right hand, the steam line is perfectly satisfactory, carrying 21 pounds almost to the point of cut-off, and cutting off at barely 20 pounds pressure. In this case the demonstration has been made inside the center of expansion for the purpose of putting the engine to a disadvantage, if it was not handling steam correctly. The valve closes at D, on C; the line C has been broken to prevent a confusion with the steam line of the diagram. A few inches to the right of D the valve commences to close. From the time the valve commences to close until it does close, the piston only travels $5\frac{3}{4}$ inches. The expansion line is very nearly a perfect one; the difference is so exceedingly small that there is nothing in practice to find fault with. The release might be improved by opening a trifle earlier. The condenser takes hold with seven pounds and runs down to eleven before reaching half-stroke and to almost twelve on the last part of the stroke. If the engine released a trifle earlier, a little more compression would be the re-

sult, and if the compression were increased slightly we believe it would make the engine run steadier, but this matter of release, vacuum and compression, is so entirely a part of the engineer's fancy, that so long as the engine runs quiet, they do not mind it, and so few of them are furnished with indicators that they really have to run the engine by their eye and ear, which is not exactly to the credit of the owners, nor in all cases to the owner's profit. For some unexplained reason there is a difference between the right and left-hand diagrams. It may have been caused by a little variation in the steam pressure between the times of taking from the different end of the cylinder, or what is much more likely to be the case, the bottom or left-hand very likely opens the valve wider, and it certainly opens it a trifle sooner than the top end or right-hand diagram. The upper line represents boiler pressure; the approximation is very close indeed on the bottom, and the amount of pressure realized on the top end is maintained very nicely, and for that reason we suppose it must be that the valve opens a trifle late and does not open fully. Practically the diagrams are very fine.

Few people have any real idea of the amount of power involved in such diagrams. Every pound of mean pressure on this engine at the speed it was running at the time these diagrams were taken, gives 117½ horse-power, the piston traveling 408 feet per minute; figuring these diagrams, we find the top end yields 2771.143 horse-power, while the bottom end gives 2747.209 horse-power; a little difference in the ends makes a very large difference in horse-power, and also makes a very considerable difference in the economy of the run. We have no data to give us the exact coal consumption of this ship. The release on the bottom at E is hardly as good as upon the other end of the cylinder, the realized vacuum at F being eight pounds only. The engines of the Providence are fitted with the Sickles cut-off, and show a very decided contrast in closing with those using the rounded wiper cam, and decidedly to the advantage of the engine.

LESSON LXIV.

LARGE LOW-PRESSURE ENGINE. ANOTHER SOUND STEAMER.

Fig. 127 was taken from the new steamer Pilgrim of the Old Colony Steamboat Company's New York and Fall River Line, after she had been running a few months. The dimensions of her engine are, cylinder 110 inches in diameter, length of stroke 14 feet, speed at regular duty 17 revolutions per minute, or 476 feet of piston travel per minute; the area of the piston is

9503.34 inches, giving as a result 137.078 horse-power for each pound of mean pressure. The diagram is taken with a 24 spring.

The line C represents boiler pressure at the moment of taking, which is 43 pounds. The demonstration in this case is made on the bottom end, from the base line A, using the parallels B B, showing the point of cut-off on C, at the intersection of C D. The expansion line, it will be noticed, runs down very closely to the actual line of the instrument after the valve gets entirely closed. That there may be no misunderstanding with reference to the line D, it may be explained that the intersection of D with C shows where the realized pressure should have been cut off to produce the amount of power from the pressure at the point A. As a matter of fact the steam valve did not close at the line D, for the pressure, it will be seen, drops away six pounds between the line C which is realized pressure, and the dotted line of the indicator, showing the difference between the indicated pressure and the boiler pressure at that point of six pounds. After the piston passes this point, the diagram plainly shows that more steam entered the cylinder, so that the volume which entered was sufficient, had the pressure been realized, to have equaled the effect of the full pressure of 43 pounds, cut off at the intersection of C D.

We think the valves of this engine might be improved with profit to its owners. To get an idea of the distances represented by these indicator lines, the release opens on the bottom end, expansion line, eight inches before the piston gets to the end of the stroke, and if it opened still sooner it would be better, for after the piston passes the center, we only realize about four pounds of vacuum, and this is increased until ten pounds is realized. When a pound of mean pressure means almost 150 horse-power, every pound of the vacuum has a value in dollars and cents worth looking after. If the release of this engine could be made slightly quicker, say ten or twelve inches, so as to be wide open by the time the cylinder reaches the center or extreme limit of the stroke, then the condenser would sooner get hold, and gave a greater effect for vacuum. The exhaust valve commences to close so that compression begins 25 inches before the piston reaches the bottom of the cylinder. In taking steam, notice the rounded corner where the admission runs into the steam line; but this very slight difference on this engine means $3\frac{3}{8}$ inches that the piston moves before the steam reaches the highest point in the cylinder. We have now 42 pounds of initial realized, while at the point of cut-off from the demonstration we have only 36, terminal pressure at the commencement of release is ten pounds above atmospheric. This valve is slow in its opening and most decidedly too slow in its closing, with regard, at least, for the engine or the economical handling of the steam.

The top diagram we have made no demonstration from, leaving it without any confusion of lines for a close study, and it has some points of superiority over that of the bottom. Its admission and steam lines are decidedly better; the release is not quite as quick, and the compression is not quite as much. Excepting the steam valve on the top end, all the valves of this engine could be quickened with benefit to it and its work. To get a proper idea of

the advantage of handling these valves correctly, we have only to refer to the amount of power shown by the diagram in Fig. 127. The bottom end shows 4935.679 indicated horse-power, while the top end taken with an intermission of one minute or two, shows 4443.479 horse-power. When we come to handle 5,000 horse-power of steam in a single cylinder and with a single steam and exhaust valve, it becomes very necessary to be careful in the adjustment, not only for the economy of steam, but as well for the wear and tear of the engine. Compare Fig. 127 with Fig. 126; the steamer Providence makes the best use of steam, being fitted with the Sickles cut-off and the Pilgrim with the Stevens. These cylinders are very large and the more perfect the adjustment of the valves, the finer work and consequently higher grade of economy will be produced. All these engines are fitted with the old-fashioned side-pipe, indicator cock in the middle, and we hope some day steam engineers will progress out of this absurd, incorrect and misleading notion. The day has gone by, when the width of a man's thumb will do in adjusting steam machinery, and the interval of time on an engine making only 17 revolutions per minute, or 476 feet of piston speed in that minute, which is required for the steam to pass through into the indicator, is quite misleading as to the actual position of the valves. Compare Figs. 116 and 117, on a small, quick-running engine, notice the difference in position between the three-way cock and the direct attachment, and multiply that difference by the difference between the 14-inch cylinder and the 14-feet cylinder, running 17 revolutions instead of about 225. In all these steamship diagrams, it has been absolutely impossible to get a short connection with the end of the cylinder, so as to show the actual position of the valves.

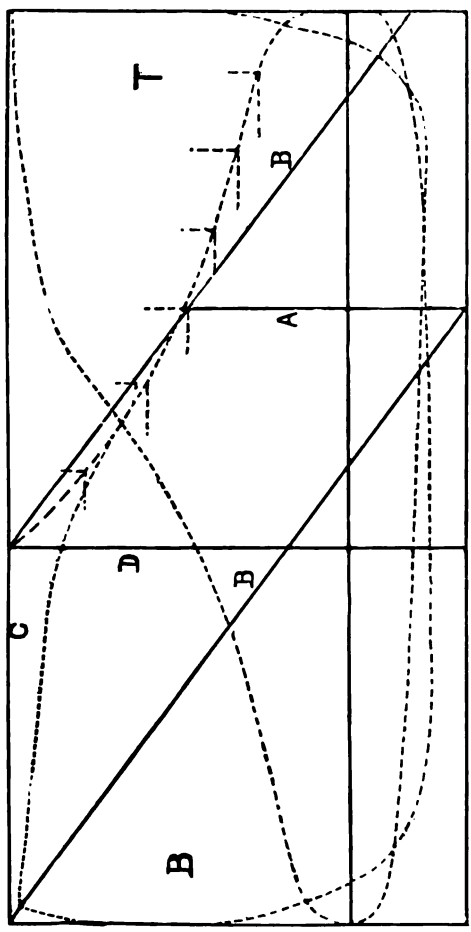


Fig. 127.

LESSON LXV.

AN OVERLOADED ENGINE.

Fig. 128 was taken from a Buckeye engine in the wire mills of a large steel works. Diameter of cylinder is 16 inches, stroke 32 inches, 95 revolutions per minute, 100 pounds boiler pressure, scale 60, indicating 240+ horse-power.

There are only two objects to be attained by showing such a diagram as Fig. 128; the first is to show the excellent handling of the steam by the valves on an engine indicating 90 per cent. more than it was ever intended by

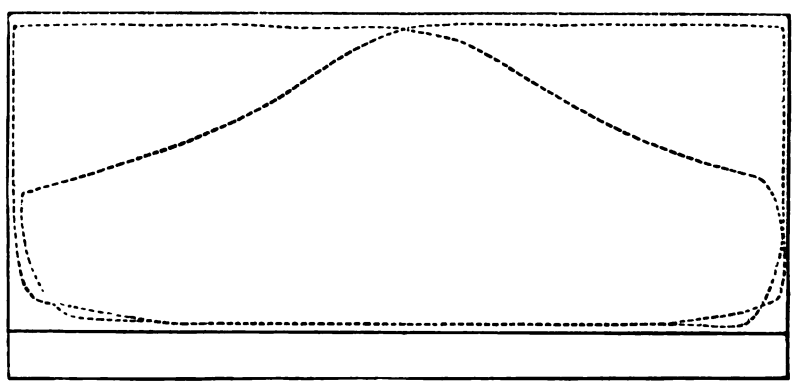


FIG. 128.

the builders, taking the rating of the engine at 125 horse-power and adding 90 per cent. to it; the other reason is to show how extremely inconsistent the owners of steam engines are in asking a load equivalent to almost double its rated power. Out of a hundred pounds boiler pressure, the engine has an initial realized pressure of 96 pounds, cutting off between 95 and 96 pounds pressure at the actual point of cut-off from the demonstration. The theoretical curve in this case follows the expansion line almost exactly, and it is a wonder how the engine relieves itself in exhausting from a terminal pressure of 46 pounds above the atmosphere, and yet the engine exhausts with a back pressure of about two pounds. The terminal pressure is almost exactly identical on both ends; there is an extremely small variation by the planimeter in the area of the two ends, and taken all in all, it may be considered as a first-class accomplishment in doing such a large amount of power. It is a credit to the builders, but no credit whatever to the owners of the machine who will abuse a good engine like this.

The practice of overloading is becoming too common. A number of very bad accidents have occurred within the past few months, and steam engine users may by-and-by become accustomed to the rational use of an engine and the proper care of it as well.

LESSON LXVI.

HARRIS-CORLISS ENGINE, OVERLOADED—FINE CARD.

Fig. 129 is taken from one of a pair of Harris-Corliss engines, running in the Exposition Cotton Mills, in Atlanta, Ga. Some repairs had to be made

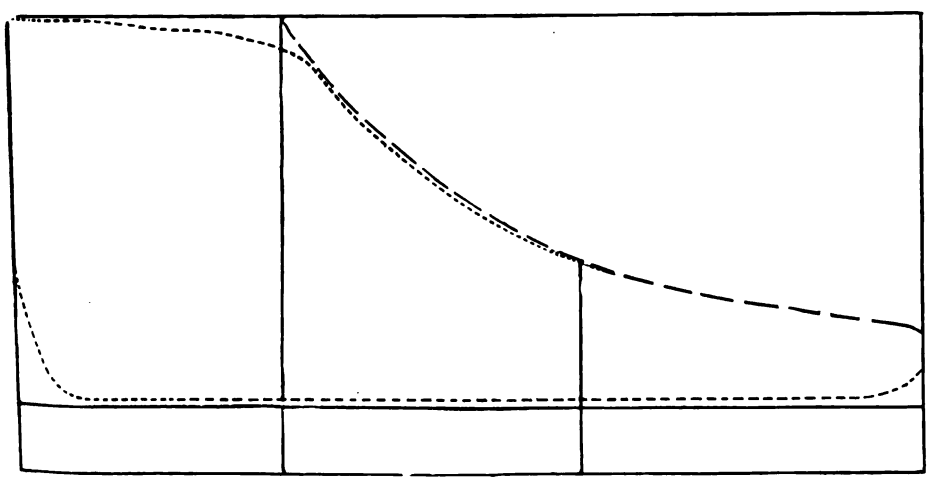


FIG. 129.

upon one side, and the other side in producing this diagram, drove the following amount of machinery: 4 pickers, 99 cards, 288 slubber spindles, 1,320 fine speeder spindles, 11,400 spinning frame spindles, 306 looms, six spoolers, four warpers, with brusher, folder and press. The size of the engine is 24×48, speed 77 revolutions per minute, scale 40, boiler pressure 83.

The production of this diagram is a credit to the engineer in charge, as well as to its builder. The engines had been in operation for nearly three years at the time this card was taken. It will be seen that the steam press-

ure realized is fully up to boiler pressure; the credit of this is due to the fact that new steam pipes have been put on by the present agent, and the engines are not at all throttled. The engine in this case is doing about two-thirds of the work of the mill with one side, and is starting with 83 pounds of realized pressure, the cut-off closes on 77 pounds, showing that the extraordinary demand for steam is much better met than in the average supply pipe, or that the capacity of the feed pipe is fully up to a large increase of load over the regular power of the engine, when both sides and its regular load are running. The expansion line by the demonstration shows but an exceedingly trifling variation at that point, and the terminal pressure is almost absolutely correct. A little earlier release would, perhaps, avoid the small amount of back pressure shown. The compression is sufficient to keep the engine working smoothly and the steam line is practically correct.

This is as fine a diagram as we may expect from practice, and in this particular case the engineer of the mills has given a great deal of attention to the adjustment of valves by the indicator, which has been backed up by a good mechanical knowledge and ability, as well as good common sense. The horse-power is 390.2509. This is another case of overloading by reason of necessity, but it is not in excess of the ability of the engine to do it very economically, and correctly as well. The ends of the engine vary less than one horse-power in total amount of load.

LESSON LXVII.

THE LATEST TRIPLE COMPOUND STEAM ENGINE.

The diagrams in this lesson are from one of the latest specimens of marine, triple compound engines, having a high-pressure cylinder in the center with a compound fore and aft. The high-pressure cylinder is 71 inches diameter, six feet stroke, running 70 revolutions per minute, boiler pressure 110, scale 40. Fig. 130 is from the high-pressure cylinder, in which J, I, represent respectively the base line of our demonstration for the top and bottom diagrams respectively. The line C is that of initial or realized pressure, D is the line of boiler pressure, A, B are respectively the points of cut-off, A for the top cylinder, B for the bottom, their intersection with the line C, marking the point at which realized pressure was cut off practically, to accomplish the pressure at J, I, respectively, at that point in the stroke. The

top diagram of this engine is somewhat peculiar, and the line A, which is, properly speaking, the volume of steam from H to A, which was used in the bottom of the cylinder, is in this case used to show where the valve was supposed to cut off from the staff of the engine; it is found by the demonstration to be entirely misleading, as the terminal pressure is 12 pounds below the real theoretical line, or below the actual point of cut-off from the steam consumed. The line A then becomes the volume of the cylinder from H to A, which was actually used at the initial pressure C to accomplish the result which is given by the actual line of the instrument, the steam and expansion lines of which are shown by dotted lines. The motion of the valve is a little late in admission on both ends, the bottom carries steam farthest and ac-

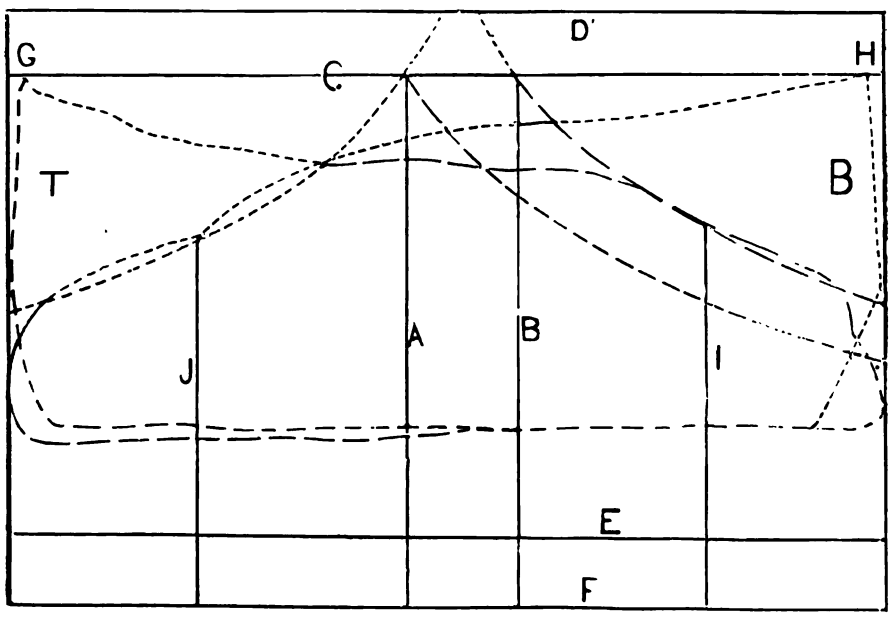


FIG. 130.

complishes the most work, the top end cylinder's pressure falls off more than in the case of the bottom, and the actual line of expansion from B, C shows a near approximation to the line of the instrument on its expansion from the time when the two lines run on nearly together; on the bottom end the line approximates reasonably close. But what shall we say to the loss of pressure, which is 13 pounds between the initial and the boiler pressure, and 10 pounds between initial and the line of the indicator at the point of cut-off, or 23 pounds below the boiler pressure at the point of cut-off on the top; on the bottom end 30 pounds is lost from boiler pressure and 17 from initial pressure at the point of cut-off. The average pressure in the receiver from the high-pressure cylinder is from 22 to 24 pounds above the atmosphere. The power developed by the bottom is 5449.5 horse-power, by the top 5054.61

horse-power, taking the actual line of the indicator. If this cylinder had cut off boiler pressure at the intersection of the two lines with D, it would have added to the bottom, all other being the same, 1184.675 horse-power, with the same expenditure of steam, and to the top would have added 1693.64 horse-power. This gives then an idea of the efficiency of the engine. The release is excellent, and we have some doubts as to the exact accuracy of these diagrams from several minor points, and we believe the conditions under which the engine is working would be more reliably shown by an improved indicator; these are the same features shown in a previous lesson, where a contrast is shown as between the old-fashioned instrument and the new Thompson.

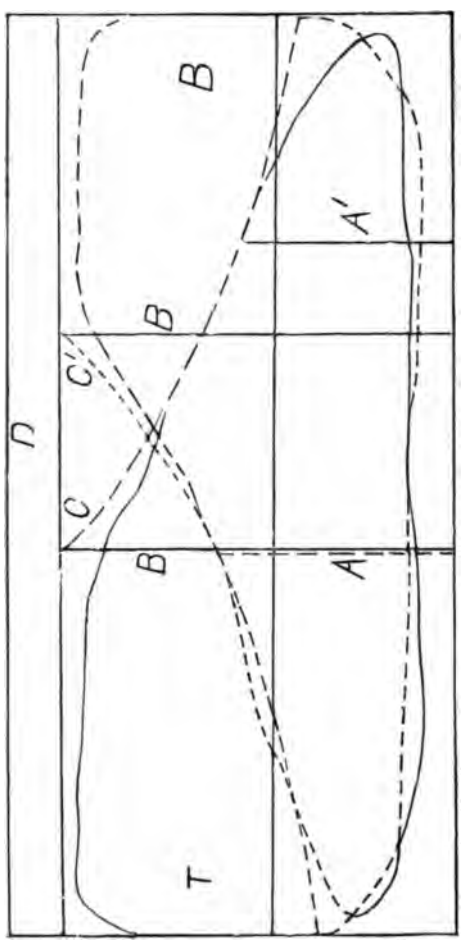


FIG. 131.

Fig. 131 is taken from the forward low-pressure cylinder 105 inches in diameter, six feet stroke, 70 revolutions, spring 16. In this case, D represents the receiver pressure from the atmospheric line 23 pounds; the top end of this cylinder realizes 17½ pounds, which falls off at the point of cut-off to 15, while the bottom end only realizes 16 pounds, falling off at the point of cut-off to 15. Both ends of this cylinder realize much better than the average low-pressure on the compound; owing to this the vacuum falls to ten pounds at one-fifth stroke and to 12 pounds at the end of the stroke, or before the exhaust valve is closed. A, A′ are the base lines. B is the point of cut-off on line of realized pressure for the top, B′ for the bottom end of the cylinder. The bottom end shows 4102.98 horse-power, the top end shows 4401.92 horse-power, with a very considerable loss between the realized pressure and the pressure in the receiver as shown by the high-pressure diagram.

Fig. 132 is from the aft low-pressure of compound, cylinder same size as the forward cylinder, same scale. This cylinder for some reason shows a very considerable increase of power and a much better realization of receiver-pressure on the top end than on the bottom, as the top end, when the valve is fully open, realizes 22½ pounds, the bottom end only 19½. The steam valve for the

bottom end of this cylinder is considerably later than the steam valve for the top end. The point at which steam was cut off is a little longer on the bottom than on the top, but the top end of the cylinder makes the best use of the steam. The release in this case is early, so that a good vacuum is obtained at the very commencement of the stroke, which is held all the way through. A very considerable loss is made as between the realized and theoretical from the pressure at A, A′, which would amount to some hundreds of horse-power. The diagram from the top of this cylinder gives 4675.25 horse-power, from the bottom 4528.68.

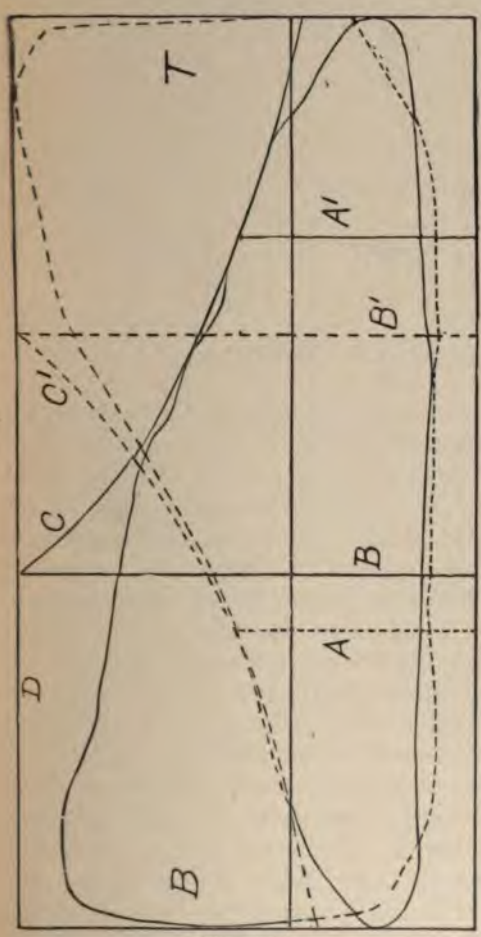


FIG. 132.

There is one point with reference to the compound cylinders that must be noticed: the practice is becoming very common of running the low-pressure with the highest vacuum that can be obtained. In this case the temperature runs from 236° to about 120°, and it is fair to suppose that a certain amount of condensation is effected every time the cylinder is filled with steam after having exhausted through the condenser. There may be serious questions as to the real efficiency of the compound engine carried to an extreme; and undoubtedly there is a serious lack of economy in working steam as these three diagrams show, as compared with the expense of maintenance, and we doubt somewhat whether this style of engine will very long continue. The power given out by the boilers in the high-pressure cylinder, including the loss in handling the steam and the resistance in the receiver, is almost 9,000-horse on each end. That which is used in the compound cylinders makes up a large volume, and the condenser increases the amount realized, but whether this cannot be done by some other combination is a question which we believe engineers shall soon study, and that the key for successfully running a large ship which requires from 12,000 to 14,000 horse-power, as does this one, lies in changing the proportion of the compound engine materially as between the different cylinders, and realizing more heat units with less refrigeration.

There must be a way of using steam much more economically than is show by these figures, which are from one of the very latest of marine engines th have not yet made their full record for economy or speed, but which ha shown a very large power; we have not been able to ascertain the relati efficiency or the actual economy when measured by pounds of coal.

LESSON LXVIII.

GERMAN BUILT CORLISS COMPOUND ENGINE.

Figs. 133 and 134 were taken from a Corliss compound engine built by the Augsburg Engine Company, Augsburg, Germany, at work in a spinning mill in that neighborhood. The information is from a series of experiments made by Prof. Schroter of Munich, but the diagrams which we illustrate we obtained direct from the director of the company which built the engine; no tracings were made use of, but original diagrams. The engine has horizontal cranks at right angles, fitted with a Sulzer valve gear, having a horizontal intermediate receiver placed below the cylinders and at right angles to them. The high-pressure cylinder is jacketed with live steam from the boiler to the admission valves. The low-pressure cylinder jacket is supplied by a branch pipe from the main steam-pipe, the high-pressure cylinder cannot be shut off but the low-pressure can. The expansion in the small or high-pressure cylinder is regulated by the governor, while the point of cut-off in the low-pressure cylinder is adjusted to any varying point by hand. The air-pump is a horizontal, driven by bell-crank below the engine-room floor. The diameter of the small cylinder reduced to inches, is 14.57; large cylinder 24.07; proportion of cylinders 1:2$\frac{3}{4}$; clearance of the high-pressure cylinder 4.3 per cent.; clearance of the low-pressure cylinder 3.1 per cent.; volume of receiver exclusive of clearance 11.548 cubic feet; volume of the receiver to the volume of the low-pressure cylinder 1:1.19; revolutions per minute 71.29; mean piston velocity 444.5 feet; stroke 37.4 inches. Reducing motions were used, made of pulleys, fixed at either end of the guide opening in the frame, on the hub of which a small drum was placed to give the indicator barrel proper motion.

The professor in charge of the test remarks that when the valve gear of steam engines are so arranged as to prevent a loss of pressure, he finds an increased economy of twelve per cent. in the result, and this was taken from two pairs of engines indicating about 300 horse-power, and his basis is made

from an actual test instead of any theoretical comparison. The deduction is also brought out that when the change of volume between the receiver and the low-pressure cylinder ranges from 0.2 to 1.2 times the volume of the large cylinder, that a mean volume of receiver equal to that of the low-pressure cylinder is the most advantageous. In the original, the metric system is used in all dimensions giving us fractions of inches.

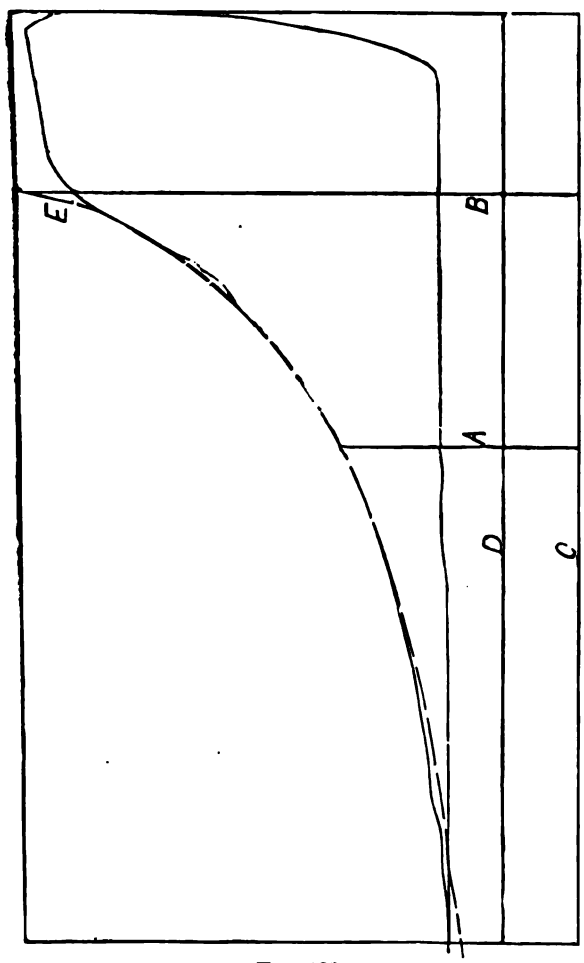


FIG. 133.

Diagram 133 on, as nearly as practicable, a 32 scale, shows a rather handsome compression, good admission, a peculiar little jog in the commencement of the steam line, but the realized pressure starts off at eighty pounds, closes on the line B with 70 pounds. The expansion line, based upon the pressure at the line A, follows very closely indeed until past the middle of the stroke, when the indicated pressure expansion line slightly exceeds the theoretical or broken line. The terminal pressure is about the limit of expansion, and the receiver gives a pressure of 9 pounds to the square inch in the exhaust at the commencement of the stroke, which increases to about 11 pounds at the middle of the stroke, and this pressure is very nearly continued to the commencement of compression. Taking the low pressure cylinder on Fig. 134, its tarts off with a realized pressure of 10 pounds; basing our demonstration on the pressure at the line A, we find the cut-off to be at the intersection of E B, at which point the pressure has fallen about three pounds. The theoretical and the actual lines run on very nearly together, showing remarkable efficiency of the expansion, but a considerable loss is realized from the receiver of the pressure given out by the receiver. The vacuum realized is 11 pounds at almost the commencement, and nearly 12 pounds at the commencement of compression.

We may judge from these diagrams that the efficiency of the live steam jacket is very considerable, and yet the same argument as in the case of the large compounds comes up in this question, the outside of the cylinder is heated with live steam and the inside is changed a hundred degrees or more by the difference between the realized steam pressure and the vacuum obtained at each stroke. There is a somewhat curious theory advanced in the lengthy report originally made upon this engine, which is embodied in the following, referring to the exact proportion as indicated by two different diagrams: "a phenomenon which goes far to disprove the necessity for employing complicated steam-distribution apparatus to attain nice lines in diagrams; and that the day is not far distant when a good distribution, by means of slide valves, will be preferred to any of the modern forms of releasing gears."

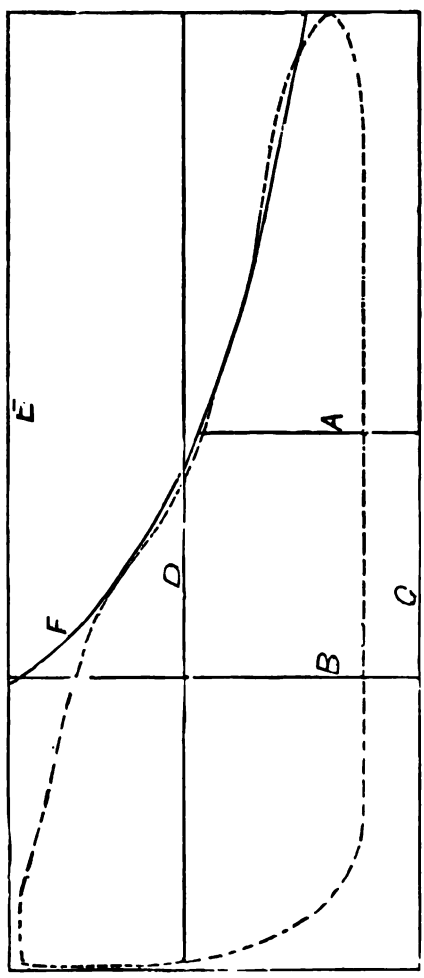


FIG. 134.

The illustrations Figs. 133, 134, show us distinctly that there is not that perfection attained in this so-called Corliss engine with some other kind of a valve gear, as will be found by the simple Harris-Corliss in Fig. 129, or the Corliss modern compound in Figs. 114, 115. The fact will not have passed from the engineering fraternity who are familiar with steam engines, that slide-valve gears, which have given the utmost perfection attainable in the nice indicator diagram lines, lately existed in the United States, but that these engines never showed an economy to compare with the Corliss, when economy of fuel, the minimum of repairs and the maximum of durability were all three items considered, and in this combination the Corliss valve gear, up to a reasonably high speed and even in marine service, when properly cared for, has outstripped every system of valves that has so far been applied, while the slide-valve gear referred to has passed out of use commercially. The feed water per hour as given in this report, with a steam jacket in use, is 14.704 pounds of feed water per hour, per indicated horse-power, but many facts embodied in American tests are not reported. Some changes were made in

the volume in the receiver which are unimportant here. Taken all in all the diagrams show very good working of steam, but nothing which would induce us to abandon the Corliss valves, or prefer the suggestion in the report upon them, of the adoption of the slide-valve in preference to the liberating valve gear.

LESSON LXIX.

MISTAKE IN THE MOTION—RESULT.

Fig. 135 shows a result not to be desired. This was taken from an Armington & Sims engine, where the parties had trouble, and the trouble was in getting more pressure in the cylinder than they had in the boiler, a consequent reaction which was not particularly desirable. A is the base line of the demonstration, B the volume of cylinder filled, E boiler pressure, 80 pounds, scale 40, C atmospheric line, D absolute vacuum, theoretical line J. The release in the diagram takes place a little before letter J, and directly under J the expansion line crosses or falls under that of the return of the exhaust which is slightly above atmospheric pressure. The valve apparently begins to close at about half stroke on the exhaust, carrying the compression up very rapidly, and at the point F the compression crosses the line of boiler pressure passing up to G which is 15 pounds above boiler pressure. Here the amount of pressure does not increase any further, but the piston continues its travel to H, at H at the end of the travel of the piston, the pressure falls to I, where the steam valve evidently commences to open, and allows the pressure to pass out, or to equalize itself in such a way that the steam line is not shown as it ordinarily is made by this engine.

It will be seen at the very outset, the point of cut-off, B E, by the demonstration, is practically inside of the real line of the instrument, but only for a very little way. The theoretical line K passes through the line of the instrument at a trifling advance beyond the line B, falling below it, while before we reach the demonstration line A, the theoretical line is above the actual line of the indicator. It then passes below it before the release, after release it barely touches the expansion line on its return.

This is a very curious diagram, for the readings are, to a certain extent, negative in every direction. What was the reason? At the left of the diagram we have drawn the whole cause of the trouble. These makers use a pendulum with an arc of a circle from which the cord is led direct to the indicator. In

this case, we found the arc of the circle reversed, or the upper dotted line instead of the lower shaded line, the point L being in either case the pulley which received the cord from the motion. There is not a single correct line on the diagram; the motion is distorted precisely in proportion to the reversing the arc of a circle, as shown, M being the center, the cord being led in the angle of the dotted line instead of, as it should have been, from below M or the shaded portion.

Upon adjusting the motion the diagram assumed its normal appearance, and entirely different from that which is shown. The question may arise in figuring such a diagram as this by the planimeter, what to measure, from the fact that there are negative quantities at each end of the diagram. We have

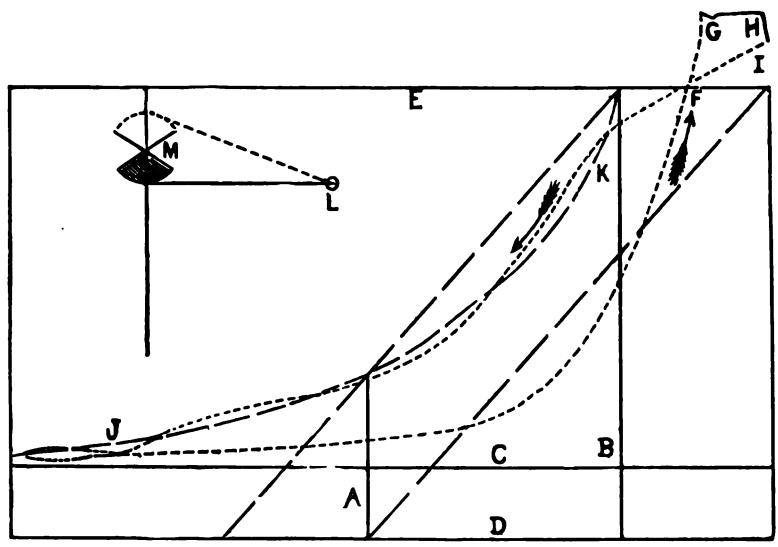


FIG. 135.

therefore drawn two arrows, one on the expansion and one on the compression line, to show the direction which should be taken. Locate the planimeter properly, start at the intersection of the line at F, follow the line in the same direction that the pencil of the indicator followed it; starting at F follow the steam line down the expansion line in the direction of the arrow, at J cross the expansion line, come up, again recross the expansion line under J, follow the exhaust and compression line in the direction of the arrow, cross F up to G, to the right to H, down to I, then down to F. This will give you the area less the negative quantities or resistance. Now as the negative quantities increase the length of the diagram, the total length from the extreme at I to the other end at the left of J, must be taken into the account, so as to get the correct ordinate which, reduced to the scale, is the mean pressure.

LESSON LXX.

DEFECTS WHICH ARE SHOWN BY THE INDICATOR. COMPARISONS.

The various adaptations to which the indicator can be put, the certainty of the readings, if properly interpreted, the different defects which may be pointed out with absolute certainty, are very frequently lost sight of, more especially when, as has been stated in this volume previously, this particular part or adjustment, or indications for defects, has been kept in the hands of men who have not understood it any too well themselves, and have not been fully conversant with the details of the machinery which they have attempted to criticise.

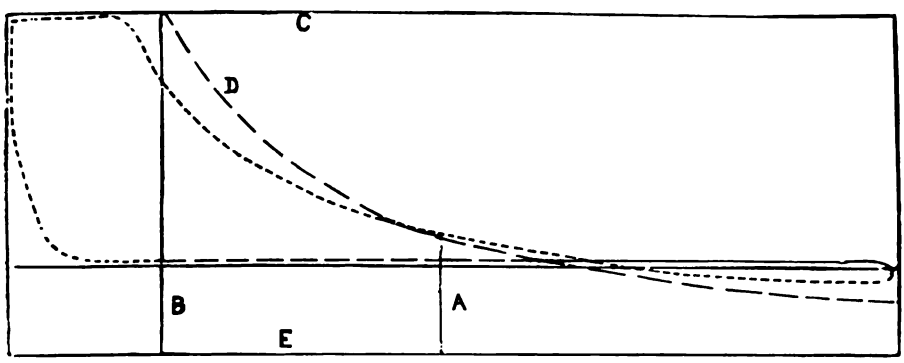


FIG. 136.

Take Fig, 136, and taking away the theoretical dotted line D, almost any engineer or engine builder would pronounce it a very fine-looking card, but the purpose of this volume is to give information. We must, therefore, resort to our demonstration, and, if we take the base line A, the scale of the diagram being 30, we find we have above absolute vacuum, a pressure of 19 pounds plus. Upon making the demonstration, we are rather surprised to find that the point of cut-off is located at the intersection of B, C, the distance from the left-hand vertical line to B, representing the volume of the cylinder in comparison to the whole length of the stroke, which was filled with steam at the initial pressure of 40 pounds, or absolute pressure of 54 plus.

Taking B as our starting point, and our readers must not forget that these are two different problems in geometry, the first problem closes with the erection of the point B, C, we then adopt the second problem, which is to lay out the hyperbolic curve, by the means already described; this gives us

the long-dotted line D, which it will be seen starts 10 pounds above the actual line of the indicator as it crosses the line B, gradually nearing the actual line of the indicator at A, and shortly after crossing below the actual line of the instrument. We find that the end of the expansion line, which is under the atmospheric line is three pounds, actual, above the theoretical, or 13 pounds above the absolute vacuum, instead of 10 as it should be. There are several theoretical questions which enter into this, that it is not our purpose to discuss, for they have little bearing upon the practicability of the application of the indicator or its readings. Our demonstration is based upon the fact that the expansion line in the cylinder is entirely settled at the point A, or about half-stroke on the expansion; or, in other words, that it is less liable to be disturbed here. Now, the point A is a positive fact, and if steam expands, according to Marriotte's law, or Regnault's demonstration, or Joule's experiments (and these are acknowledged as approximate to the fact) then the actual pressure at A gives the point B C, as where the initial pressure of 40 pounds should be cut off and expanded, according to these different authorities, to produce the pressure at A. In this case the point A is higher on the expansion line than it should be if the steam had been properly cut off previous to B, showing that something must have occurred while the piston traveled from B to A, which admitted steam into the cylinder after the cut-off valve closed, as is shown by the indicator line. Now, this may be admitted in so small an amount as to apparently be imperceptible, and the demonstration is the only way of ascertaining what does occur. In this case, the steam was admitted after the cut-off valve apparently closes, but in such a small amount that at A it is sufficiently high above what it should be, to throw the point B forward on the line C, and the other end of the expansion line quite corroborates this, the sequel proves the correctness of the application. When the engineer who submitted the diagrams to us, was allowed an opportunity to take down his engine, he found a bad leak under the steam valve, so much so that he had to draw-file the end bearing of the valve, or shoulders of the valve, to let down upon its seat, and to stop the leak, which was visible when the cylinder head was removed.

The old-fashioned way of taking the terminal pressure and working back, would be a very wrong practice in connection with this diagram, and there need not be any confusion in the minds of any of the readers of this work, who correctly apply the demonstration to any diagram, if the few simple directions are followed which are so plainly given. It will at once settle the fact, that something is wrong, without stopping to experiment.

If, now, we take up the case of another series of complications, defects and conditions not desirable, we will refer to Fig. 137, the scale of which is 40, steam pressure at the time of taking, 82 pounds. This was a new engine built to run 83 revolutions, and was sent to us from several hundred miles away. The actual diagram is reproduced; A representing the base line of our computation, B the point of cut-off at which the initial pressure C of 50 pounds was equal to cutting off in the amount of steam used to produce the pressure at A. Had the theoretical line F been run to the boiler pressure

line D, it would have shown that the use of about one-third the amount of steam, properly cut off, would have performed much more work, if it had not been for other defects, of which we shall shortly speak. The diagram, in this case, shows on its cut-off and expansion line, an exceedingly close approximation to the side of an old-fashioned iron wedge. It is extremely difficult to locate the point of cut-off, or to find out where the expansion line begins, and the approximation to anything which is valuable or economic is so entirely remote that we will not waste further time upon that portion of the diagram. The theoretical line F shows a close approximation of the terminal pressure as between the theoretical and actual, demonstrating that an amount of steam bounded by the line B, cut off on C, was about equivalent to the amount of steam used, taking the assumed line F with the actual line of the instrument.

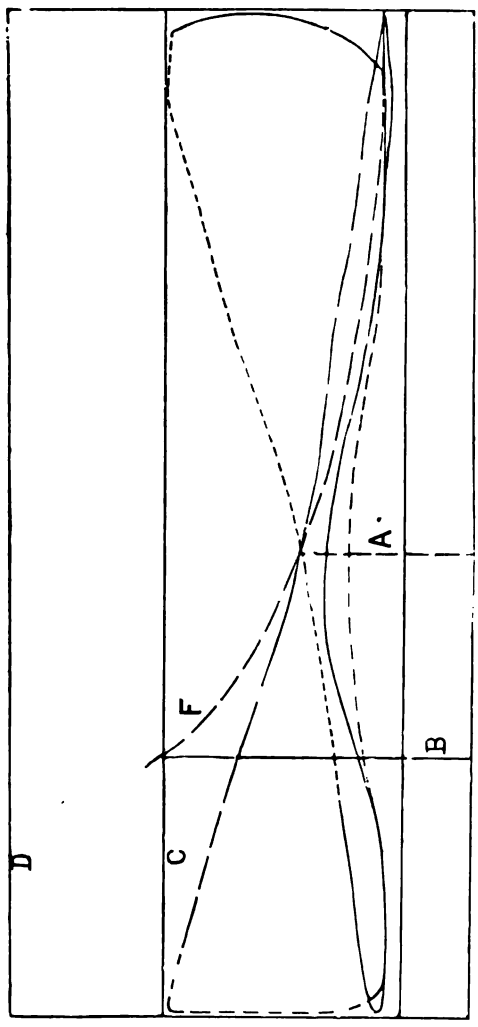


FIG. 137.

In this case, we find the extreme terminal about in unison with the theoretical, but back of that where we suppose the exhaust valve commences to open (for the lines are indistinct and indefinite) it is several points higher. But the main feature now is, the trouble in getting rid of the exhaust steam, one line is dotted and the other is solid; they have both a peculiar hump, showing either that the exhaust passage is clogged by insufficient ports, or what is more apt to be the case, and what we at once decided when submitted to us, that the steam from one end of the valve passed into the exhaust about the center of the stroke, for a brief space of time, increasing the back pressure. A variety of theories were advanced, one of which was that the valves were not tight, but would in time wear down to a seat. Whenever an engineer finds this kind of a diagram, the shortest way out is to abandon the whole thing, or condemn the engine and get it into the scrap-pile as soon as

possible. It is so exceedingly extravagant in its use of steam for the small amount of power, and considering the fact that it was intended as an automatic cut-off engine, that it is unworthy further attention, its only purpose of introduction being that it is an incident in practice which may be valuable to some one in trouble.

As the best way to judge between bad and good practice is by comparison, we introduce into this lesson another diagram, which was not taken by the Thompson indicator, partially to show the expansion line, about which more or less argument has been made among indicator makers for the last few years, and also to contrast it, with the circumstances all stated, with Figs. 136 and 137 in this lesson, and the four succeeding figures in the next lesson following.

Diagram Fig. 138 is an exact reproduction, taken from one of George H. Corliss' steam-jacketed new pattern engines, boiler pressure 75, 30 inches

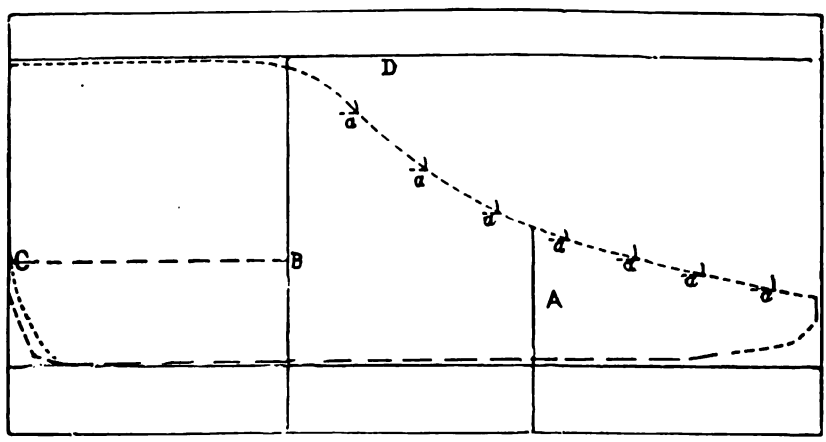


FIG. 138.

diameter of piston, 72 inches stroke, 54 revolutions, 40 scale. This engine is driving a flour mill in the City of New York, has been running 3½ years, about 140 hours per week, and from six o'clock Monday morning until six o'clock or midnight Saturday night, the throttle valve is never closed. The engine is grinding about 1400 barrels of flour every 24 hours and its weekly run amounts to 143 hours each week. The indicated horse-power is about 575 H. P. We have 66 pounds initial pressure out of a boiler pressure of 75; the line A is the base line of the demonstration which gives B D as the point of cut-off on D, or the volume of the cylinder represented by the dotted line C D in proportion to the whole length of stroke, as that portion of the cylinder which was filled with steam at initial pressure to accomplish the work. Making the demonstration from A B, by means already described, we have the points *a*, *a*, *a*, etc., showing the exact line of the theoretical in comparison with the actual. The line D is drawn triflingly above the actual line of the instrument, or nearly two pounds above, in order to show the actual record of the indicator; for that reason, a slight difference is made in the position of

the lines, showing the points through which the theoretical curve runs, but whatever that difference may be, it is so near to the width of a line as to be a feature of no possible account in variation, and would be hardly recognizable had the line D been drawn directly through the steam line of the diagram.

There is no mistake about the work which this engine is doing, provided the indicator is correct, and it is hardly probable that any great difference exists with the action of the indicator; but there is a point in connection with this expansion line which is treated of in the next lesson, to which our readers will do well to pay careful attention, and that is in relation to the change of pressure, volume, temperature, etc., and whether the expansion line in this diagram is an absolute reproduction of fact; this will be illustrated in the immediately succeeding lesson.

With regard to adjustment of this engine, little can be said other than if we were ourselves adjusting the valves, we should give it a slightly earlier release, so as to let the exhaust line down where it belongs, and this in turn would give us the fine dotted line for compression, which we should much prefer to see. This diagram was not taken with any preparation, change or otherwise, but was taken while the engine was at its regular work, and speaks not only for its builder, but as well for the care which has been given it by the chief engineer. This shows an exceedingly close approximation as between practical and theoretical, where everything is in working order, well taken care of, doing severe work and running for practically twenty-four hours per day, six days each week. No new valves and no lost time are yet charged to this engine.

LESSON LXXI.

AN EXPERIMENT WITH INDICATORS ON THE SAME END OF THE SAME CYLINDER, AT THE SAME TIME, WITH THE SAME SPRINGS IN EACH.

Fig. 139 was taken from a $9\frac{1}{2}\times12$ Armington & Sims engine, running 276 revolutions per minute, 80 pounds of steam, 40 spring. The pattern of indicator with which this was taken, is what is now known as the old Thompson, with what was practically the Richards parallel motion, or a very much heavier motion than that which is used on the Improved Thompson of to-day. Some of the indicator makers have put out some very curious literature in the way of circulars, showing the defects of each other's indicator, according

to the figures which accompany the circulars or pamphlets which have been spread broadcast. The experiment which we are to record here, was made for the purpose of ascertaining what the indicators will do, in actual practice; and we desire at this point to call the attention of our readers to what we have very radically differed from many of the engineers, with reference to the expansion line of the instrument, and the record which is made by the action of the indicator on particular points, and we are glad, therefore, to show Fig. 139. At A we have a realized pressure of 76 pounds, at B 35 pounds, at C 16 pounds, at D 9 pounds, and at E the expansion line crosses the atmospheric line, and when the exhaust valve opens at the termination of the stroke, the pressure rises gradually until about one pound above, when it returns across the expansion line at E, passing along, gradually increasing to F as the valve is closing, until at F it is closed, when the pressure rises rapidly. This diagram is one of many, and is taken without any particular selection.

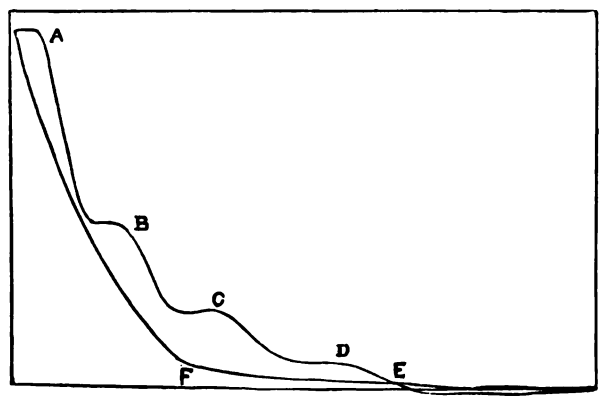


FIG. 139.

We will now refer to Fig. 140, which was taken by another indicator, with the same spring as stated above. The two diagrams, 139 and 140, were taken on the same stroke of the engine, with the same steam pressure, each indicator run by a separate cord, and a slight difference in the length of the cards is shown. The peculiarity of the two cards is perfectly perceptible to any one. In Fig. 140, we start off at A with a pressure of 65 pounds initial. At B we have 51 plus, at C 48, at E 27, at F 15, at G 8. A, however, is the height of the compression line which falls off to D, rebounds to B, comes down to C, during the time that the valve is opening, and then starts off to the left, making the first curve in the steam line. The rebound of pressure, by the sudden expansion, increase of volume, and the struggle between the elements and the speed carry the expansion line below the compression line on the card, and when the next fluctuation in pressure occurs, at E, in the forward movement of the engine, and the rapid expansion and falling of pressure, the expansion line crosses the compression line, making the second wave at D; dropping to F, it covers, but does not cross, and then advances

again, the oscillations becoming less and less perceptible, until they barely cross the atmospheric line at the end of expansion, and come back upon the atmospheric line alone until the compression line is made. There is such a radical difference as between the two diagrams that one must be nearer right than the other, and one must be exceedingly far from correct. We have settled in our own mind that 139 shows the position of the valves, and the action of the steam.

But there are other elements to be brought into this lesson. It has been upon one part of the indicator-using fraternity, their earnest endeavor to reconcile all differences of position, all fluctuations of working, to the idea of making a smooth card, for which see 140, 142. We have frequently had cause to say editorially, and before different audiences, that we had been unable to reconcile all these differences which do take place in the steam cylinder of an engine, to the theory that a steam engine indicator must of necessity produce

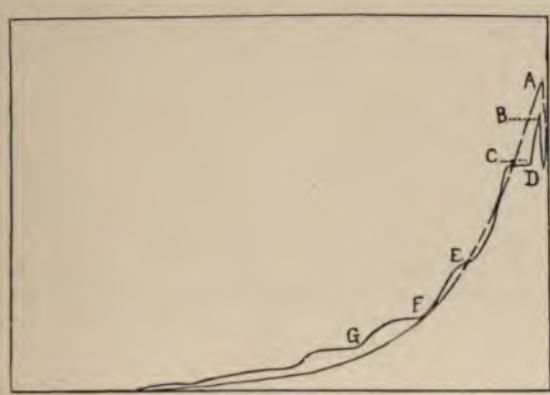


FIG. 140.

the true hyperbolic curve, or the nearest approximation to it, with a correctly working indicator. Inferentially we have condemned this as all wrong, and believe that the various elements entering into the expansion line of high speed diagrams, if correctly delineated by the indicator, will very much more approximate 139 and 141 than they will 140 and 142, both as to the position of the valves, and actual record of the working of the steam in the cylinder. If we take 139, we find from A to B a change of 41 pounds pressure, in 140 we find from C to E a change of 21 pounds pressure. If we take the temperature of the steam at A on 139, we find it 308.4°, at B it is 259.3°, while at C it is only 216.3°. Let us now see what the volume in each case is. At A the volume is 377, at B 764, at C 1572. If this were the only element it would be quite enough to produce the radical changes shown in 139. If, now, we refer to the dotted lines, showing the friction load, in Fig. 142, we find there a diagram taken with a stiffer spring, which almost absolutely ignores any fluctuations in temperature, pressure or volume. Referring to the solid line in 141, which represents the friction card, with the Thompson indicator, with

the same spring as 142, we find these differences very elegantly shown in the load, and plainly perceptible in the friction card, which is enclosed within the other. Both these diagrams in 141 and 142 were taken by preparing for it beforehand, so as to throw a break upon a pulley, properly connected, raising the load from the friction to the amount shown, in the shortest space of time consistent with safety to those employed. Now, if nothing except the volume and the temperature were to be considered, we have then elements of immense disturbance, as shown by the figures quoted. In Fig. 139 the volume increases in the fraction of a second from 377 to 20,890 at E; while in Fig. 140 the volume increases from 434 to 20,890, and the temperature diminishes in the fraction of a second from 308.4° to 102°. But if we refer to Mr. Charles T. Porter's book, entitled the "Richards Steam Engine Indicator," which has been in our possession for fifteen years at this writing, we find the most reliable and best tabulated data that we have ever yet had access to, with reference to the speed of the crank at different degrees in the steam engine, as well as to the speed of the crank as compared with that of the piston. We

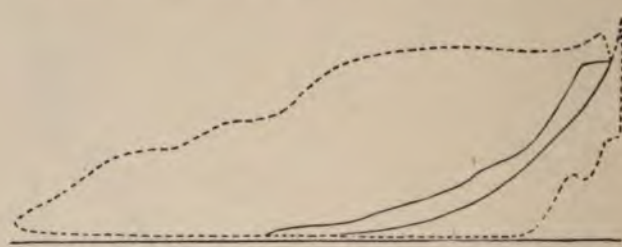


FIG. 141.

find the following statement with reference to the rotative force exerted upon the crank, being the same for equal divisions of the diagram:

"If the reciprocating parts of engines were without weight, so that the pressure of the steam was always exerted upon the crank precisely as it is on the piston, then the rotative force on the crank of the steam pressure would be equal for equal divisions of the diagram measured at any part of the stroke. This is often denied, and still more often doubted. Being a fact, it ought to be placed beyond either denial or doubt. The motion of the crank is supposed to be uniform, passing through equal arcs in equal times, the motion of the piston, on the contrary, is, first, scarcely two-thirds that of the crank, being to the latter in proportion of 1:1.5708, and, second, it changes at every point of the stroke. At the instant that the crank is on the dead center the piston has no motion. Then its motion, at first infinitely slow, becomes gradually accelerated, until the velocities of the piston and the crank are equal, when it begins to be retarded, the ratio of retardation increasing until on the opposite center its motion has ceased. But whether the revolution of the crank is uniform or not,—as in fact it can never be absolutely, since then the fly-wheel would cease to act as a regulator, and might be dispensed with,—the motion of the piston has a fixed relation to it, being equal

(if we disregard for the present the effect of the angular vibration of the connecting rod) to the versed sine of the angle which the crank makes with the center line. The study of the table of versed sines will explain all about it. We will employ the two extremes for illustration. The versed sine of 1° is .0001523; the difference between the versed sine 89° and that of 90° is .0174524. Therefore, the length of the crank, or of the half stroke of the piston, being 1, while the crank is traversing the first degree the piston moves the distance .0001523, and while the crank is traversing the ninetieth degree the piston moves the distance .0174524, which is nearly 115 times greater than the former. The rotative effect of a force varies also as the versed sine of the angle at which it is applied. Therefore, the effect of the rotative pressure of the steam on the crank while it is traversing the ninetieth degree is 115 times as great as while it is traversing the first degree, but also the piston moves in the former case 115 times as far as in the latter. It follows, therefore, that equal movements of the piston, or equal portions in the length of the diagram, at any part of the stroke, represent equal rotative effects upon the crank."

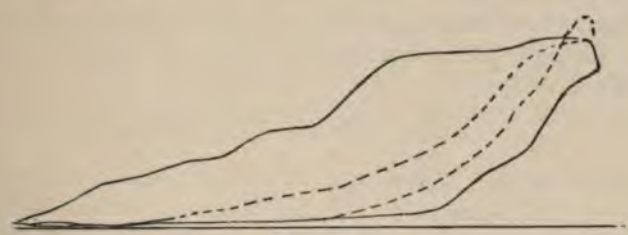


FIG. 142.

We have made this lengthy quotation, first, because Mr. Porter has so well said, and has substantiated his assertion by indisputable fact, and, second, while we are not dealing in this lesson with the rotative force on the crank we *are* dealing with the speed of the piston, and will now drop our digression and return to the subject in hand. Added to the extreme range in temperature, as well as the tremendous increase in volume, we have now another factor which shows us that the difference between the travel of the piston through the first degree of the stroke and the last degree of the stroke is 115 times; we have then precisely what we require to substantiate our own assertion, that if the indicator is to be the exponent, or is to truly record what is actually done in the cylinder, then it must also record these extreme ranges of fluctuation in pressure, volume, temperature, all of which are governed by the varying speed of the piston. We have, therefore, just these elements; referring to diagrams 139 and 141, from A to D, in 139, the speed of the piston is constantly increasing, the pressure of the steam, as shown by the indicator diagram, falls very rapidly, the temperature decreases very fast indeed, while the volume increases at a tremendous rate; the speed of the engine, being 276 revolutions, reduces the time in which this diagram is made to about one-tenth of one second, or that portion of it which lies between C

and D is reduced to $\frac{1}{20}$ of a second $\frac{1}{1200}$ of a minute approximately, more correctly being $\frac{1}{1104}$; and when we add to this the fact that the speed of the piston is an ever-varying amount—anything but constant—we do not hesitate to state that while our assertion may have been doubted or denied, it is susceptible of proof, and that proof we believe is offered in these elements beyond dispute, if the facts are considered.

Figs. 141 and 142 were taken with a 60 spring to ascertain what difference, if any, would be shown as between two instruments on the same engine, at the same speed, with the same steam and spring, and at the same instant of time; 141 was taken with the Thompson instrument, with the new or Improved Thompson, with the light parallel motion. In 141, we have dotted the outside or total load and drawn the friction of the engine, so far as we could do, in a solid line. In Fig. 142, we have been obliged to reverse this operation, owing to the fact that the friction crosses the initial. The two diagrams may be treated from any standpoint, and only require a careful observation to convince any person, who is disinterested, where the actual position of the valves and the working of the steam is shown. To our own idea 141 shows every element of accuracy, while 142 shows quite a different result for power and position of the valves; and we may in this connection, perhaps, with perfect propriety, quote again from Mr. Porter's book, as follows:

"VIBRATIONS OF THE SPRING.

"Sometimes at very high speeds, or with very sudden action of the steam, the spring of the indicator is put into vibration. If the line produced by these vibrations is a waving line, quite free from angles, this is an evidence that the action of the instrument is frictionless, and the mean of the vibration gives a true line." Almost on the same page Mr. Porter makes this statement: "There are no vibrations or pulsations of steam in the cylinder; all appearances of this kind, on the expansion curve, are caused by the spring of the indicator being put into vibration by the sudden action of the steam."

If the vibrations do not occur while the engine is under motion, or if the pulsations are not caused by the conflict in the molecules of steam, or steam and water, as well as the different mechanical forces, then we confess that our steam engine indicator had better be laid upon the shelf instantly, there to remain until we can prove that different mechanical forces, acting as we have cited above, are capable of producing a true hyperbola by means of a spiral spring. Whatever may be the fact with regard to pulsations, we call particular attention to the difference in the outline which shows the position of the valve, as between 141 and 142, while the differences between 139 and 140 are quite sufficient for anyone, however unsophisticated he may be in the uses or abuses of the indicator. In our own experience in taking diagrams with different indicators upon the same end of the engine, at the same speed, and under the same conditions, we have found that diagrams showing wavy lines, figure somewhat less power, and give generally a more accurate idea of the working of steam in the cylinder, and that the same indicator also sooner

responds to any actual alteration made in the valve motion, by showing it upon the diagram, showing that its accuracy extends into this important realm of the functions of the indicator, viz.: position of valves, while the stiff-working indicators do not show it as soon nor as delicately.

LESSON LXXII.

EXTREME HIGH SPEED, DIFFERENCE IN INDICATORS.

The tendency to high speed has led to some very curious developments, and one of the principal claims of engine builders, as well as indicator makers, to-day, is, that their engine, or their indicator, is the most, if not the only, reliable one at high speed. High speed, it has been proved to our

THOMPSON, No. 2.

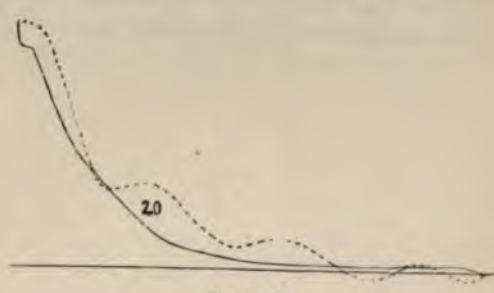


FIG. 143.

own satisfaction, has a limit where efficiency ends and extravagance begins, and while we have no purpose in this article to criticise, we must express our opinion so that we may not be placed on record as advocating the speed (at which the diagrams illustrated in this lesson were taken) for practical purposes.

These diagrams were taken in the shop of Armington & Sims, Providence, R. I., where they had prepared an engine by increasing the strength of some of the parts of the regulator, and our intention was to have carried the experiment to 700 or more revolutions per minute. Diagram 143 was taken with a Thompson Improved Indicator, No. 2, on small paper barrel, an illustration of which is given with this, which differs from the larger indicator only in the size of paper barrel, and some minor changes with reference to the stand, the spring and motion being the same as that in the larger

instrument. This instrument is made with or without the detent motion, generally with the detent motion; this is a matter which is invaluable to those who are unused to high speeds, or are not familiar with the practice of

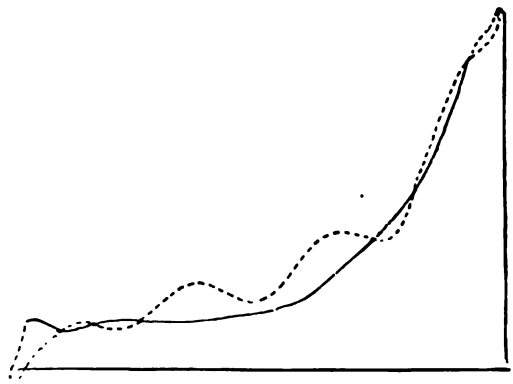


FIG. 144.

taking indicator diagrams, and it is especially valuable to those who are taking diagrams from the locomotive. Fig. 143 was taken with this instrument in April, 1884, at a speed of 536 revolutions per minute, actual count, the regulator being graduated and adjusted for that point. The reader will necessarily have to compare several diagrams, one with another; for this purpose, with the exception of Fig. 149, we have in this article, dotted the steam line and drawn the expansion line solid in all the figures.

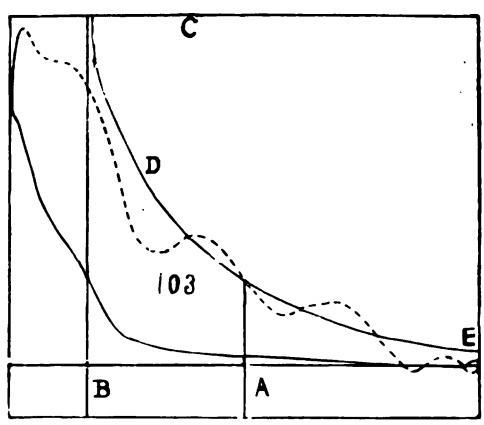


FIG. 148.

In Fig. 143, it will be seen that the expansion crosses the atmospheric in the vibrations, and returns again, making a very handsome atmospheric line, and that the compression line crosses the first or largest vibration, but that the steam line is very handsomely shown. Fig. 144 was taken by an instrument from another maker; it will be seen in this case that there is a very great difference between the atmospheric line and compression line.

Fig. 143 was taken with a 50 spring, 144 with a 40 spring. Fig. 145 was taken with the same instrument as 144, at a speed of 536 revolutions; there being such a difference between 143 and 144 as to position, that 146 was

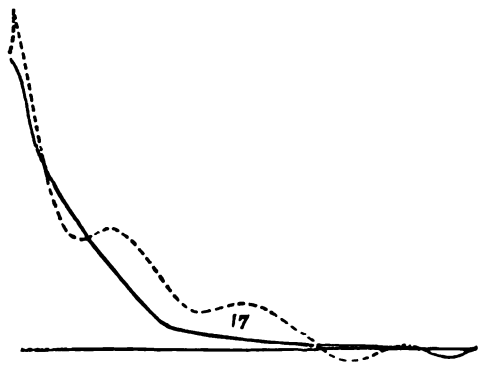


Fig. 146.

taken with the little Thompson, the spring being changed to 40, the speed being increased to 562. It will be noticed here that a change takes place in the admission and steam line, which continues through the other diagrams, the motion of the valve being shown as a trifle late, the expansion line having its peculiarities, but the record being very clear. The steam pressure in 146 was 75 pounds. To ascertain what could be done, we again changed the spring to 50, the steam meantime having been raised to 95 pounds, and obtained from this change Fig. 147, with the Thompson No. 2, revolutions 562.

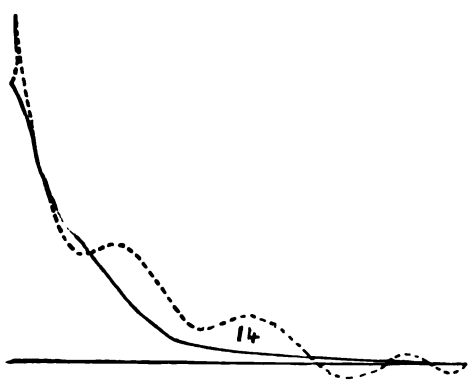


Fig. 147.

For the sake of experiment, arrangements were then made to add a load to the engine, and Fig. 148 was taken with the Thompson Improved No. 2, steam pressure 92 pounds. The peculiarities in 146, 147 continue with reference to the valve motion, showing it a trifle late; the compression and expansion lines are very nearly identical, except that the load is increased. Upon 148 we have erected the demonstration from exactly half stroke, the line A being the base line, showing the cut-off to be at B, on C, and for the

terrific speed at which it is running, there is a very good showing for the valves as well as the indicator. Having so far determined that the action of the indicator was at least capable of showing changes, an effort was made to

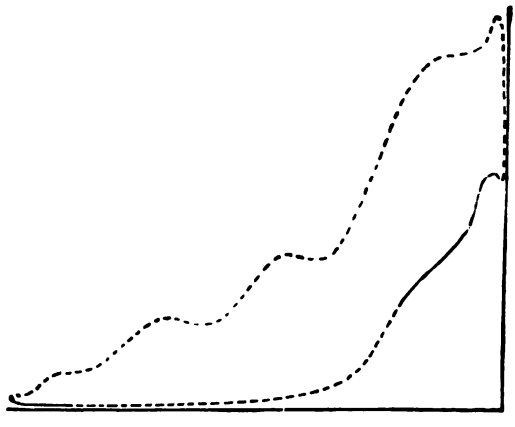


FIG. 145.

increase the speed of the engine from 562 to 700, the regulator was changed as much as it was deemed safe and a start was made, producing Fig. 149 with the new Thompson No. 2, at a speed of 642 revolutions per minute. Two other cards were produced, and while changing for the fourth one, a piece of the regulator which had been made of steel, straightened out by the strain upon it, and we were treated to an example of solid bodies going off at a

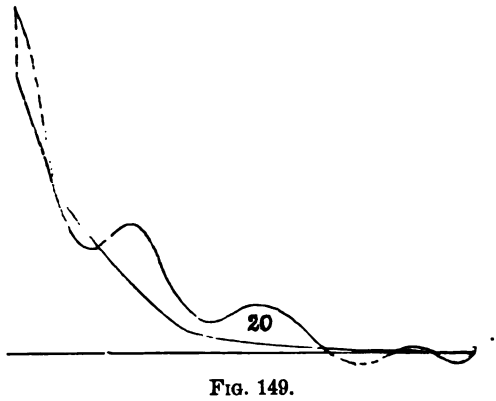


FIG. 149.

tangent, and the engine was stopped for repairs. The ordinary speed of this engine is 320 or 330 revolutions; the action of the regulator shows plainly on 149, with 95 pounds boiler pressure, and an initial of 90:92, the load was made constant, but it is absolutely impossible to engrave the variations which took place, only at the curves in the expansion line. The intention at the outset of this experiment was to try the three indicators which are in the market; one of them stopped inside of 400, one ceased its

accuracy practically at 536, or probably below, while the third one made the diagrams which we have shown, leaving the little Thompson master of the situation in this experiment.

We have, since that time, been allowed to test an engine more for speed than anything else, and have succeeded in getting very fair diagrams at above 720, but the action of the steam shows plainly that the engine will not become a merchantable or commercial affair, and there is no use in devoting space to that which is not practical; we do not consider this lesson as one of any particular importance for the student of the indicator, and it is introduced more as a curiosity to show the results of a single experiment, upon which we do not place any particular stress, and would not advise any person to buy the Thompson indicator solely upon what is shown in this lesson, or not to buy either one of the other two because of their ill success at this experiment. One of the makers of the engine was present and saw all the experiment. The intention was fully pursued of giving to each instrument every benefit and every advantage, and the results shown are, as nearly as possible, the actual result of the work of the instruments. We do not, however, advise our readers to adopt any such speed, nor do we consider the actual indicator diagram at this speed as an unquestioned performance. The claim has been made that diagrams have been taken at above 1000; while we have no reason to doubt the assertions, we consider them simply experimental, or in the light of a curiosity, and having no possibility of practical value, unless it be to gratify a whim, which cannot result in any economy to the general steam user, at least with present engines, indicators or mechanism.

LESSON LXXIII.

AMERICAN BUILT COMPOUND STEAM ENGINE FOR A RIVER STEAMER.

The question of simple condensing engines, or of compound engines, for our river steamers has been one upon which a great diversity of opinion has been expressed, and in which the extremes of practice have been worked out within the last few years. Wishing to get data regarding this, we asked and obtained permission to indicate a river steamer's compound engine working a screw, and this steamer is doing the work with about one-half the fuel that a condensing beam engine did it, and is one of the fastest steamers for her class running out of New York.

Fig. 150 is the high-pressure diagram, taken with a 50 spring, the cylinder being 30 inches in diameter, 36 inches stroke, making 88 revolutions per minute, with 85 pounds of steam.

Fig. 151 is from the low-pressure cylinder of the same engine; 56 inches in diameter, 36 inches stroke, making 88 revolutions, scale of spring 10. The diagrams were taken at the same instant of time, two indicators being used, so that they represent what was done on the same stroke at the same instant of time.

In Fig. 150, A is the base line of the demonstration, which touches through the theoretical curve G, the realized steam pressure line F, at B. B represents the volume of steam actually used to do the amount of work at the realized pressure, which is 9 pounds less than the boiler pressure E. The valve in opening, as will be seen, allows the pressure to drop slowly from the line F after the piston has passed but a few inches of its stroke, so that at the point B, on F, the realized pressure by the indicator is 10 pounds less

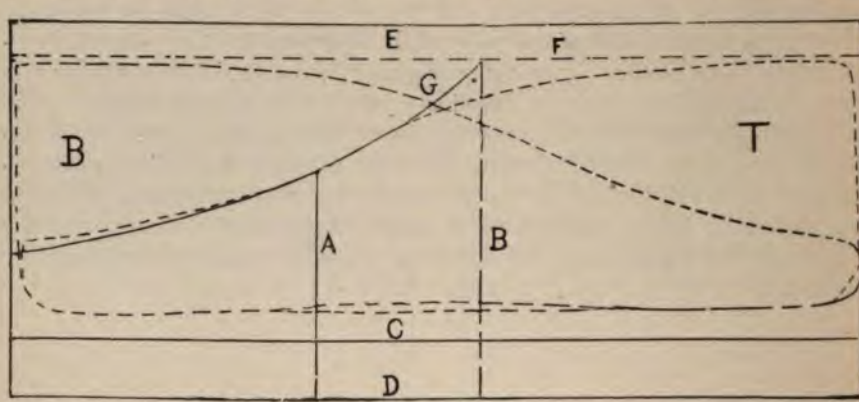


Fig. 150.

than the realized pressure at the commencement of the stroke. We then find, after having passed pretty well toward the end of the expansion line, that the expansion rises above the theoretical to a certain extent. The exhaust valve is somewhat slow in its opening, and the pressure in the receiver at the very highest amounts to between 11 and 12 pounds. The same general features will apply to the valves, both high and low-pressure cylinders, viz., that the opening of the valve seems to be either slow or insufficient, and the pressure gradually drops from and after the time when the valve opens, and owing to this feature it is also slow in closing, and the amount of steam accounted for is considerably in excess of that which is generally considered shown by the indicator. If we refer to 151, taken with a 10 scale, we charge against that cylinder 12 pounds initial pressure, which is the extreme amount shown in the high-pressure cylinder as back-pressure or between the high-pressure and low-pressure cylinder. The lines I and I′ represent respectively the steam admission from the receiver to the low-pressure cylinder. If we refer to the line I we see that after the steam is first introduced the pressure is kept at

11 pounds above the atmospheric line C for a very small portion of the stroke; that as quick as the speed of the piston begins to increase, then the pressure of the steam commences to drop away, until at the line B there is only 4 pounds above the atmosphere, and at the point of visible cut-off, or where the valve finally closes, there is only two pounds above the atmosphere. I′, while not making so good a start, has a pressure of almost three pounds at the visible point of cut-off, which is considerably beyond the line B′. Now, what happens? When the valves of this engine commence to open, the steam is not admitted in proper amount, owing to its low tension, to fill the cylinder at the pressure which exists in the receiver. The moment the piston starts to move away from the end of the cylinder—and the motion of a piston with a short connecting rod, not more than two cranks, accelerates

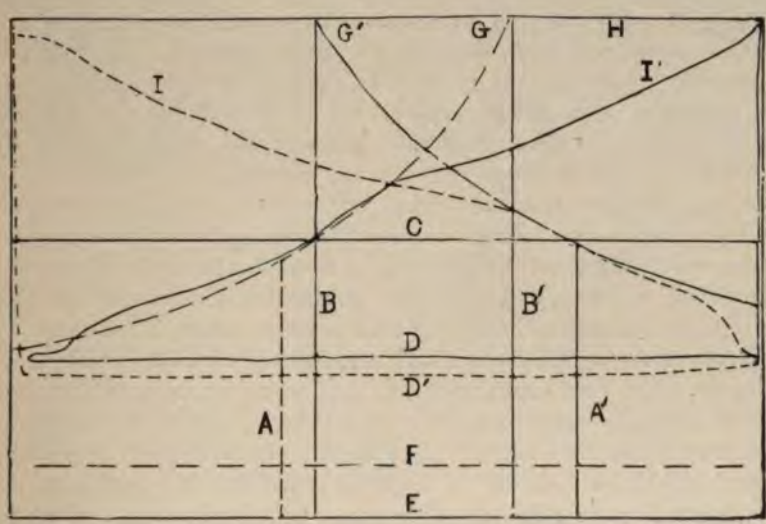


Fig. 151.

very rapidly—then the amount of steam which is admitted grows less and less or is more and more wire-drawn. The steam is cut off at the line B′ of the other diagram, as we express it, visibly; or, that is, the point, almost two-thirds of the stroke, where the steam valve closes and the expansion on the low-pressure cylinder begins. If we go a step further to the line A′, which is the base of our computation, we find at that point, only a trifling distance beyond the point of cut-off, the pressure above absolute vacuum is about 14.3 pounds. Now, had we here cut off the pressure of steam at B to make the theoretical line G′, we should have used the same amount of steam, practically, and have expanded down the line G′ without the outlay of a single pound of coal more than we are now using, while on the other side the dotted theoretical line G would have cut off at B′ and have gone down the dotted line, utilizing the space bounded by H, I, G as efficient pressure on the piston, instead of following the steam lines I and I′. This is serious,

but we will shortly show by the figures what would be produced with a proper arrangement of the valves. The line D is the vacuum line on one diagram, and D′ the vacuum line on the other. It will be noticed there is a peculiarity with reference to the vacuum of this engine. We have only 6.2 pounds on one end and 7 pounds on the other, or practically 12¼ inches and 14 inches; the coarse dotted line, F, shows what we should have realized in obtaining a vacuum of 12 pounds or 24 inches. Those diagrams were taken on the night of December 18, 1884, when the water was certainly cold enough to have produced a good vacuum, but the proportion of the machinery would not allow it. Here, then, we have the difference between D′ and F, which should have given us 5 pounds more of mean pressure effectually, or of mean effectual vacuum more than we did receive.

These are the general features and facts with reference to the diagram. The engine is well built, well proportioned, seemingly, and the boat is very fast and economical. Now, suppose we could improve it in design or in execution, what would be the effect? In the high-pressure cylinder we have in the respective ends 520.25 horse-power on the bottom, and 508.7 horse-power on the top; in the low-pressure cylinder, the actual diagram by the indicator figures 389.24 horse-power on the bottom, and 332.55 horse-power on the top. If the valves had worked, so that we could have obtained our theoretical diagram by opening the valves sufficiently to feed the cylinder with the pressure, cutting it off sharply so as to make the theoretical lines or close approximation to them, and only have obtained the same vacuum which is shown by the instrument, we would then have attained relatively 499.46 horse-power on the bottom and 402.72 horse-power on the top, making a very radical gain. But if we could make this engine still more perfect in its working, so as to admit the steam, cut it off and then produce the vacuum of 12 pounds, we should have had a very different result indeed; it would then have been 683.15 horse-power on the bottom and 616.29 horse-power on the top, or to condense it, the actual diagrams combined show now 852 horse-power on the top and 897 horse-power on the bottom. With proper increase, it would give 1136 horse-power on the top and 1191 horse-power on the bottom, or would make a still further difference of a very large amount in proportion to the coal which the steamer burned, if these results were realized. The receiver pressure is well taken care of by the low-pressure cylinder, but the whole amount of steam is not accounted for as between the high and low-pressure above the atmospheric line, and the account below the atmospheric line on the low-pressure cylinder should by some means be very radically improved. It is quite possible that the ports and passages, and probably the throw of the valves in this engine, are all based upon the olden-time practice and would, upon careful investigation, be found to be too small in area or too short in valve travel, and yet, as compared with previous practice, this steamer has a splendid record. The only question now is, how much higher the record can be made by proper adjustments of the engine.

LESSON LXXIV.

A COMPOUND NON-CONDENSING ENGINE.

Very frequently diagrams are put before an engineer to ask his general opinion, and while there is no information of a positive sort to be gained from this lesson, it is entirely within the province of the work to show some things with which working engineers are frequently annoyed or expected to do work with or against natural obstacles, in their way, which preclude economy, regulation of speed, or any other practical result. Referring to Fig. 152, we have the high-pressure side of a compound non-condensing engine, scale 30. This is supposed to be governed by a throttle governor in the pipe, which jumps up and down like a jack-in-the-box; the different lines here are precisely as the indicator left them. It will be seen that the initial

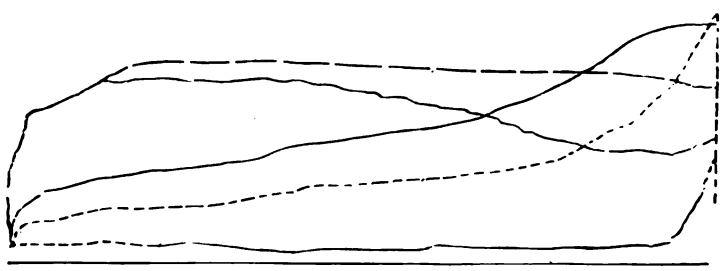


FIG. 152.

pressure of steam entering the cylinder in the highest instance is 38+; it then varies to 27, and from that down to 18. Notice, that in two of the lines an attempt is made to cut off, and in the other two lines, strange as it may seem, initial pressure is below the maximum pressure by several pounds. The back pressure amounts to between three and four pounds at the commencement, and runs down to one and one-half pounds at the moment of compression.

Fig. 153 represents the low-pressure side, running as high-pressure in connection with 152. This arrangement was brought about by shifting a valve between the cylinders, so as to allow direct steam to enter into both ends and sides. The scale of 153 is ten. We have here 13 pounds initial, but with an exceedingly great variation in the action of the steam, commencing with a back pressure of two pounds, running up to four, and dropping back to three, showing that there is some peculiar action in the cylinder. Fig. 153 was taken after 154.

Figs. A, B, 154 are from both ends of the compound cylinder, and were taken at the same instant as 152, scale ten. We have an initial pressure in

the A end of 7 pounds, which falls down to 1½ pound by a most peculiar line. It then runs along and gradually increases to 2 pounds, and a little later to 3¼. Whether this obstruction is caused by the peculiar passing of the steam through the double-ported slide valve between the cylinders, or whether it is caused by the motion of the exhaust valve, we have not determined, not being enabled to examine the inside or working parts of the engine. The expansion in either case is most peculiar, and the terminal of this double expansion line seems to be slightly below the atmospheric, but we have the same general formation of the return or exhaust line which passes above the line of direct pressure more than half a pound, falling back again slightly and compressing above the induction pressure. The diagram, taken altogether, is peculiar. It shows but an exceedingly small amount of power exerted upon the piston as the back pressure nearly neutralizes the forward pressure. Turning to the B end of the cylinder, we have, if anything, a worse diagram than the A. The features, it will be noticed, are very similar indeed in general, but there is a little difference of outline. The extreme amount of initial pressure is only about five pounds; that barely continues for an inch of the stroke, when what we suppose to be

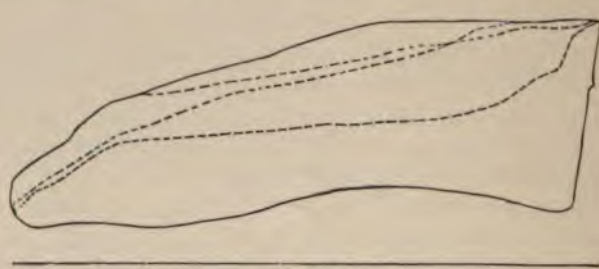


FIG. 153.

the expansion line, falls away similarly to that of the A end, resting on the atmospheric line for an instant of time and dodging away again to a pressure of nearly three pounds at the maximum on the second introduction of steam. In the exhaust, for a very brief interval, the line returns on the atmospheric pressure line, then rises very materially above the direct steam line continuing two pounds above the atmospheric line with only five pounds of initial pressure. It is usually supposed in compounding that some gain is to be derived. In this case there is no economy, and what the gain can possibly be by compounding a high-pressure engine with another high-pressure cylinder, one side doing eight and one-half times as much power as the other, we cannot imagine. The high-pressure side of this engine is doing from seven to eight and one-half times the amount of power that the compound is doing. We think the idea of high-pressure compounding is entirely a mistake, unless some very different way of working it out shall be adopted from that shown in this lesson. The movement of the governor was most erratic, and we have no doubt, if the different parts of the engine were compared with a correctly moving valve motion, that all the ports and steam passages would be found

radically differing from good practice, and that the travel of the valves was very ill-proportioned to the travel of the piston. They simply take their place as curiosities, and for information to the working engineer, which, we hope, very few of them will ever encounter, especially if they are compelled

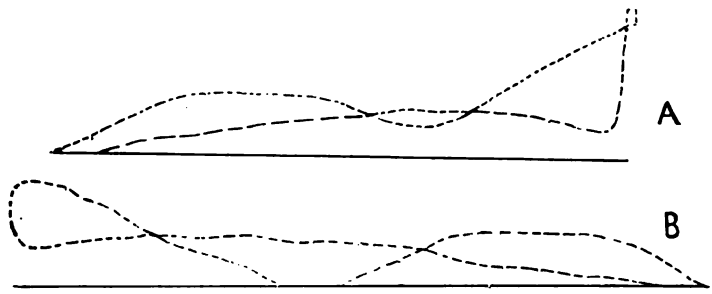


FIG. 154.

to take charge of them. This engine is burning more than eight pounds of fuel per horse-power per hour, if the data given of the amount of coal burned is correct. The diagrams were taken to ascertain certain facts, by the writer's hands and indicator.

LESSON LXXV.

FISHKILL-LANDING CORLISS.

Fig. 155 was taken from a Corliss engine, built by the Fishkill Landing Machine Company, 18×42 inches, running 63 revolutions, steam pressure 68 pounds, spring 30, heating a portion of the mill by exhaust steam. This diagram was taken from an engine in its every-day work, without making any changes, as the attachments were made at noon-time. The point was to get at the average work of the engine, as well as the load upon it. Very little need be said of it, other than that the valves of the engine seem to be in admirable condition for working, although, for best results, we would quicken the action of the steam valve slightly so as to avoid the rounding corner between admission and steam lines, as well as to obtain nearer approximation to boiler pressure, if possible. The demonstration on this diagram shows a very close approximation to first-class practice. We would prefer a trifle earlier release so as to obtain a little more compression, but, taken all in all, the diagram gives a very excellent handling of the steam, and shows plainly that the

valves are tight, and that the vibrations in pressure are taken account of by the indicator. The approximation to boiler pressure is but in small measure due to the late opening of the steam valve, (61 out of 68 pounds are realized) but rather to the crooked steam pipe which has in it more or less valves, and through which steam is drawn for dyeing as well.

If the reader should be at all skeptical as to the absolute necessity of expressing the clearance on a diagram to obtain the result for which we make the demonstration, let him add two per cent. to the length of the diagram and then make the demonstration. Some engineers and others who have had but little experience with the matter frequently attempt to show that no

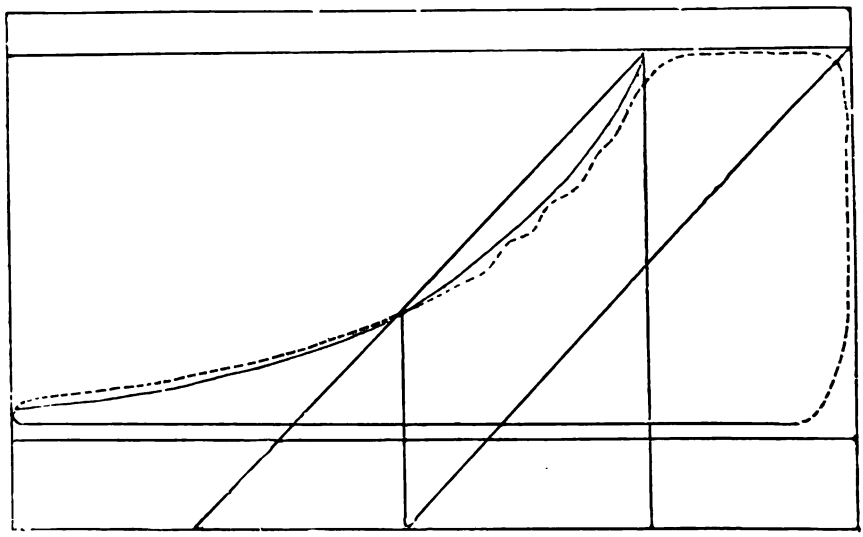


FIG. 155.

demonstration is correct upon a diagram without adding the volume of clearance, and whether it is guessed at or otherwise, it is necessary. The volume of clearance added to this particular diagram will not vary the expansion line more than the width of it, and for the purposes for which we make this demonstration will not allow the planimeter to discover any difference, but if we are figuring for the amount of water per horse-power, or steam per horse-power, the clearance is necessary in order to insure the correctness, but if we are looking to show what a certain pressure at a certain point will require cut-off at a certain point, to accomplish that base line the clearance is no more necessary in a computation of this kind than is the reading of a thermometer out-doors.

LESSON LXXVI.

AN OCEAN STEAMSHIP COMPOUND ENGINE FITTED WITH CORLISS VALVES.

Figs. 156 and 157 are from an ocean steamship, fitted with English engines and English-built Corliss valves. If we refer first to 156, the solid line diagram is precisely as the instrument left it. It is not a diagram that is pleasing to the eye from its general appearance or proportion, nor indeed is its mate when divested of the test of its efficiency. These were pronounced by several chief engineers to be very rough-looking diagrams, and so the general reader might term them; but as we are dealing not in proportions, but for information, we will apply the test and see. In the dotted diagram we have taken the absolute pressure at A from the absolute vacuum line D, which we find to be 54 pounds. Upon working the demonstration, as duly explained in previous lessons, we find that the realized pressure cut off at the point C E, gives the actual pressure at A upon the proper expansion of the steam. The theoretical line E, which is drawn dotted, shows plainly that the same approximation exists in the correct working of steam, as is shown from the time the steam valve gets open at the commencement of the diagram up to the point where the amount of steam equals the cutting-off at the point C E. The theoretical line in this case follows the actual expansion line for quite a distance so closely as to avoid any cause for criticism. The departure of the line of the instrument from the theoretical line shows plainly where the valve commenced to open to allow the steam to exhaust. The release is very good. We now come to a point in which there is a radical difference between the valves and those of some engines which are shown in this volume.

We find a receiver pressure at the commencement of exhaust of five pounds, the maximum pressure is between seven and eight pounds, barely reaching eight, while the terminal or commencement of compression is about seven. There is a greater difference in the action of this engine with reference to the receiver and the high-pressure cylinder in their relations to one another, than in that of almost any other large marine engine diagram shown in this volume. This steam line falls away but slightly, and we have an initial pressure of plus 70 pounds, which falls to 68 at about one-fifth stroke, and at the point of cut-off we have 62 pounds out of 70, showing that the capacity of this valve to furnish steam at the maximum pressure or initial pressure, is almost equal to fully one-half of the volume of the cylinder in its steam supply, while in the slide-valve engines, as a rule, we find a diminution of pressure varying all the way from 7 to 25 pounds from the

initial, and in some cases exceeding even that. This might lead us to consider whether the perfection of valve motions is increasing or decreasing, so far as actual results go, upon the other marine engines of new construction.

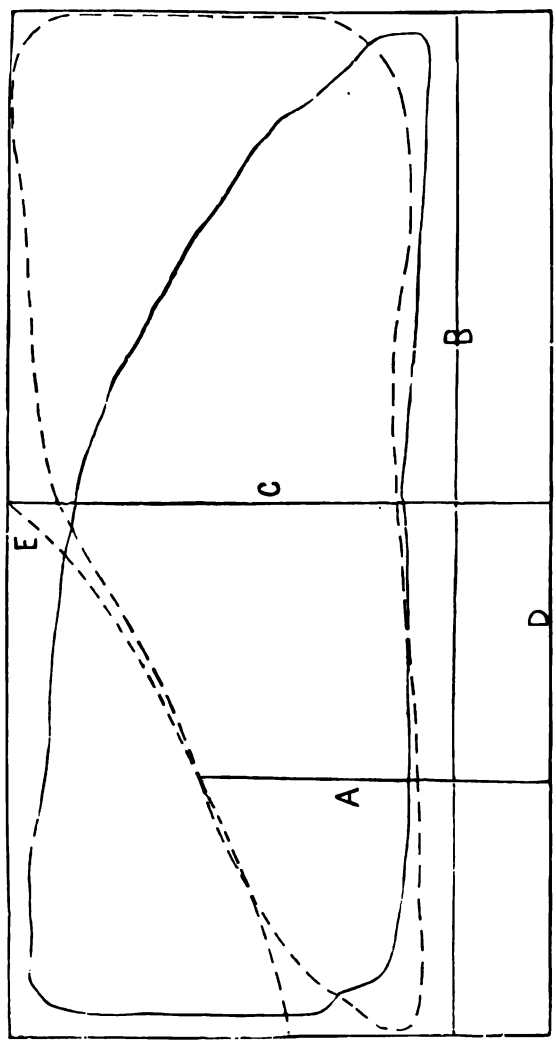


Fig. 156.

It is a self-evident fact from the diagrams, that while the compounds may have accomplished certain results with a less expenditure of fuel than that which has previously been accomplished, that there is still room for a vast improvement in the marine service, over that of the old-fashioned beam, or high and low-pressure engines, and whether this cannot be carried very much further so as to compare with the best stationary practice, in spite of the difficulties which beset the marine service, is not a question upon which much discussion can be had if the economic factor is a predominant one. This diagram, 156, so far shows the highest economic efficiency of any marine diagram we have yet obtained.

If we now turn to Fig. 157, which is from the compound cylinder, we have charged against this cylinder the maximum pressure in the receiver from the high-pressure cylinder diagram. It will be noticed that there is quite a falling off, and it is not the proper way, but in this case it has been deemed preferable, so as to see what loss was incurred from a possible one, taking the initial pressure as the maximum pressure of the high-pressure cylinder. If we take the realized pressure in the compound cylinder, it, if anything, is carried rather better as an approximation to a straight line than that in the high-pressure cylinder, the reason for which is undoubtedly a larger valve area. The demonstration in this diagram, taking A as the actual pressure

from the absolute vacuum, gives us 13¼ pounds, and, taking the initial pressure as stated, gives the cut-off at the point C and the theoretical line E. In this case the approximation is exceedingly close, and the terminal theoretical pressure varies slightly above the terminal of the expansion line, as it will do whenever this basis is taken. If we are using a steam of lower tension than we really charge in our computation, its terminal pressure must be expected to be somewhat above the terminal of the theoretical line, for volume and tension must both be taken into account. The release in this case is not equal to that in the high-pressure cylinder. The expansion according to the theoretical is 4¾ pounds below the atmospheric line, while the actual line is precisely 4 pounds below. The commencement of the vacuum is between eight and nine pounds, gradually running down to between ten and eleven on one end and eleven and twelve on the other. The question may readily occur as to this effect in the economy of the engine; in our own minds a vacuum of twenty-four inches, or twelve pounds, is preferable to one of twenty-seven or twenty-eight; the question has been often asked but never answered, why should we use fifteen or twenty men at the mouth of the furnace in throwing in coal, and a donkey engine at the other end of the engine doing its level best, to produce a temperature of from freezing down towards zero on the alternate ends of the low-pressure cylinder, calling for its equivalent in heat at every filling of the cylinder with steam? The probability is, the engineer who has charge of this ship has found that he can run his feed-water a good many degrees hotter with a twenty-four inch vacuum than with one which goes lower, and, we have no doubt, that in that respect he is entirely correct.

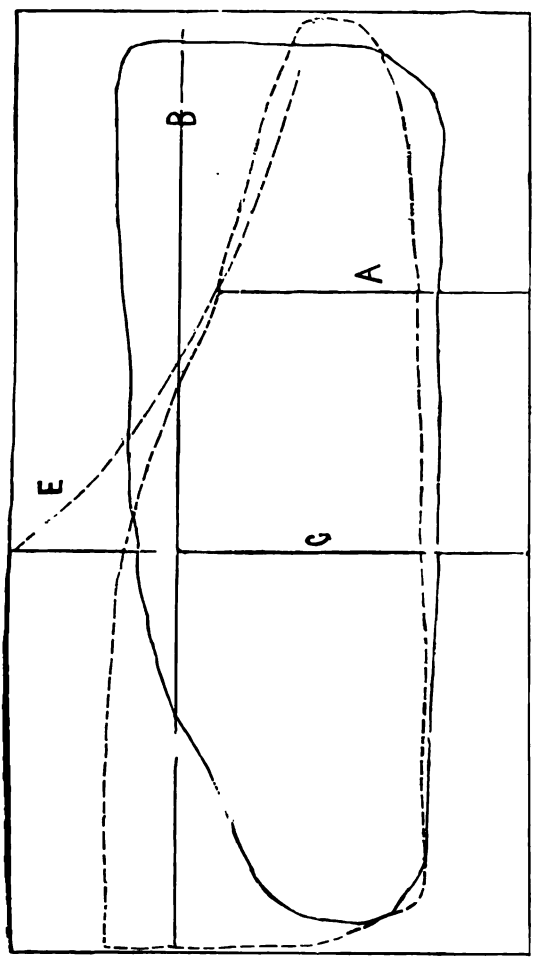


FIG. 157.

There is another thing which may be said of steam engine diagrams as taken from marine engine cylinders. We have been allowed to examine a great many steamships, and we have never yet seen proper or fully correct appliances for taking of diagrams. Usually the side-pipes are connected at the bottom of the cylinder, a round turn made and then connected on the side near the top. A three-way cock is arranged above the grating and the motion is taken from any convenient point. The clearance between the indicator and the bottom of the cylinder we have measured where it has had three times the distance to pass upon the bottom of the cylinder than on the top, for the steam to pass from the engine into the piston of the indicator, and for that reason we usually find the bottom of most marine engine diagrams latest, the corner most rounded, and it is not impossible that such is the case with 156 and 157. While the diagrams show practically the amount of power used, they show only an approximation to the actual in the valves, and the further removed the indicator is from the piston, the less is the accurate working condition of the valves shown or known. These two diagrams in 156 and 157 have a great many points of study for the practical engineer, and they show at once an entire difference in the handling of the available pressure, from that of most of the marine diagrams which are illustrated. The full dimensions of the engine and the boiler pressure are not given; scale of the high-pressure diagram is 30, that of the low-pressure, 8.

LESSON LXXVII.

ANOTHER OCEAN STEAMSHIP COMPOUND ENGINE.

Quite a contrast in practice from the preceding lesson, and yet one of the best engine results, will be found by a reference to Figs. 158 and 159, which are from one of the recently built steamships with high and compound cylinders, the high-pressure being 52 inches, compound cylinder 93 inches in diameter, length of stroke five feet six inches, revolutions 62½ per minute, pressure in boiler 90 pounds, scale high-pressure forty, compound twelve, vacuum gauge 25, hot well temperature 114°. The high-pressure cylinder has piston valves, the compound has slide valves.

Taking 158, our base line A shows that the cut-off occurred at the intersection of C D, D being the realized pressure, and C representing the volume of the cylinder in its proportion to the length of stroke that the line D is to the whole distance between the two extreme vertical lines. The theoretical

curve E shows that the loss from initial pressure to the point of cut-off is 13 pounds, total loss from boiler pressure at the point of cut-off 19 pounds plus. The theoretical curve follows more closely than we would suppose after it strikes the line, running but very slightly below it. This would probably be accounted for by the fact that the steam is slightly superheated. The action of the valves in this case was very nearly perfect, so far as being tight go; the release is early, and the counterpressure in the receiver commences at eleven pounds, increases to plus thirteen, and at the point of commencement of compression is between fourteen and fifteen pounds. The point at which compression ceases and the steam valve commences to open, shows an almost exactness of 43 pounds upon either end of the cylinder; this is a point of very material economy in a quick-acting engine like this, which is quick-acting for so large an engine. The steam lines are carried very well, and the open-

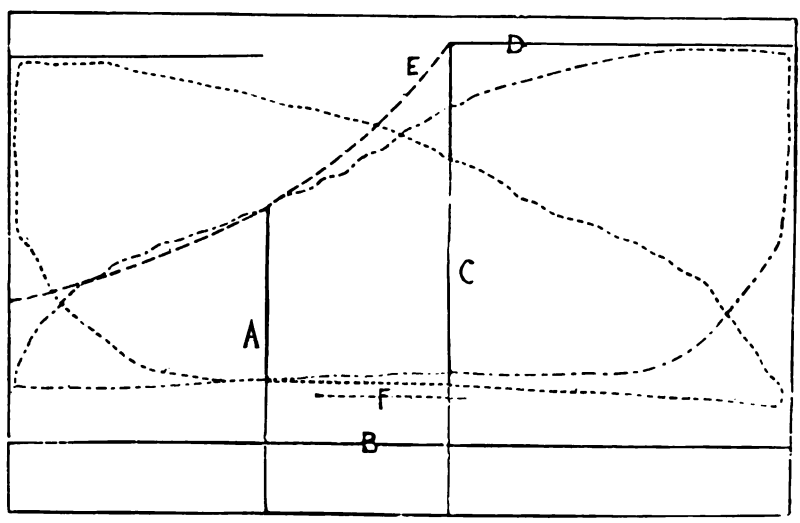


FIG. 158.

ing of the valves is very nearly right in both cases. This is a desirable improvement over that of some of the steamships which still maintain the old-fashioned slide valve, or even the old-fashioned piston valve with slow speed in its whole length of travel. In this case, we have no doubt the valves of the engine are not based upon the old-fashioned idea of valve travel, and yet there could be a radical improvement if they were speeded still higher in their proportion of travel to that of the piston of the engine. Possibly a little increase of travel would aid it.

In diagram 159, we have again charged the engine with the full amount of the maximum pressure in the receiver. One end has 13 pounds plus for its initial, while the other end only gets 11 pounds, and it will be noticed that the end upon which we have erected the demonstration, the main valve is considerably later than on the other end. This, without any doubt, accounts for

a portion of this change, and the contrast, as between the admission and carrying of steam in the two diagrams, shows the most radical difference between that of 158, the fact being 158 is piston and 159 slide valves. The opening and closure of valves in 159 show plainly that they are very slow in both motions, whether the passage ways are sufficient or not can only be told by actual demonstration from measurement, but it is a self-evident fact from the indicator, that the admission of steam on the left-hand diagram of 159 is exceedingly slow. The valve is also slow in its motion, and the pressure drops away much faster than on the other end of the same cylinder. This is sometimes accomplished by having the valves so balanced for opening that the real travel of the valve never reaches wide open on that end, while upon the other end of the cylinder the valve, having been cast solid and finished, had a travel which may be slightly earlier in its opening, and, owing to the angularity of the rod, quicker in its movement. In this case the theoretical

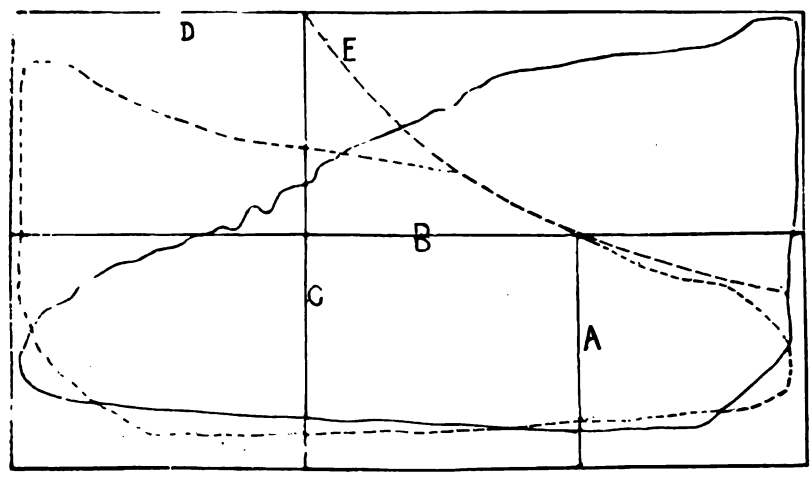


FIG. 159.

curve follows closely, after the actual line of the instrument and the theoretical curve meet. In this case, our demonstration base A shows an actual pressure at the very point of crossing the atmospheric line of 14.7 plus above absolute vacuum. The line D represents the maximum receiver pressure, and the working out of the two problems on the base line A gives the point C on D, from which the quantity of steam at the pressure of D should have been cut off to furnish the pressure at A; and in the computation for power or fuel consumption, the amount of steam used between the valve's opening and closing, was equivalent to the pressure cut off at C on D, so that while the valve was not closed at C, its closing was equivalent to an increased pressure, and a diminished volume of the cylinder filled at that pressure to accomplish what was done at A. The release on both diagrams is very good, generally considered, but the right-hand end diagram seems to have some kind of a struggle going on which makes a curiously-shaped expansion line, or in the

closure of the valve evidently causes some vibration in the pressure which is not fully accounted for. The solid-lined diagram commences with 9 pounds of vacuum, runs down to plus 11 pounds, compresses on about 12 pounds, and takes steam about the crossing of the atmospheric line. The other end of the cylinder commences its vacuum at about 10 pounds, running down to plus 12, as it could readily do from the less amount of steam used upon that end of the cylinder.

The two diagrams, 158 and 159, were taken by a Thompson indicator in order to ascertain the exact power, and as nearly as possible the position of the valves. It would be very interesting if short connections, and a positively correct motion could be arranged for this pair of engines, to get at the facts with reference to the actual position of the valves from a close connection to the cylinder, and the closest approximation to a positive and correct motion for the instrument.

LESSON LXXVIII.

CONDENSING CARRIED BEYOND ITS ECONOMICAL APPLICATION.

In Fig. 160 we have an old Corliss engine, which has been running night and day for a number of years, twenty-two inches diameter, forty-eight inch stroke, running 500 feet per minute piston speed, independent condenser, twenty-four spring. In this case the amount of steam actually used by the engine is represented by the line A, one end of which touches the admission line, and the other the dotted line, which is the boundary of the proportion of the cylinder filled with steam. The demonstration is made from the line of

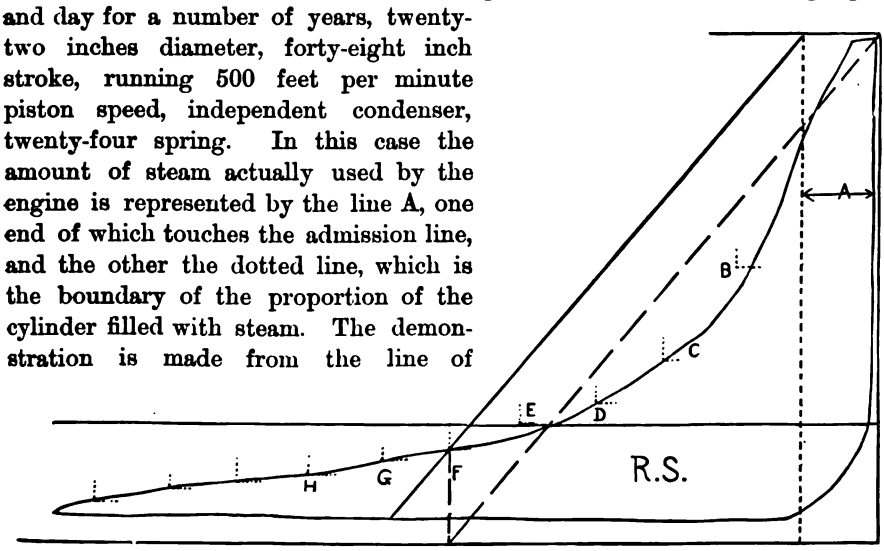


FIG. 160.

pressure F. Apparently the engine cuts off very much shorter than where the dotted line is drawn, but upon the demonstration we follow down the dotted corners of where the ordinates cross the lines, forming the boundary of the theoretical curve. At B we find that the line of the indicator or actual is below the theoretical, at C the actual line is but very triflingly below. Now what happens between A and B, or B and C? Nothing more or less than that the valve does not close tight, or else that it leaks after having closed and before it is firmly seated. From C to D the steam continues to come in; at E the expansion line is below the theoretical and it shows to the eye, comparatively, that the line drops. It is undoubtedly caused by the much more rapid expansion of the steam. At F the lines are together, and so on, getting a trifle above before the end of the stroke. There are several points about this worthy of notice, the first, that the expansion line is somewhat irregular, and the second is that the drifting which occurs from one point to the other is fully proved by the location of the theoretical and the actual lines. The vacuum, in this case, reaches nearly twelve pounds, or twenty-four inches; very many of our oldest engineers, who run condensing or compound, claim that at this point it is by far the most economical, as the temperature of the water at this particular point is much more advantageous for re-use or for feeding than as though more vacuum was obtained. The high range of change of temperature between even the terminal pressure of 3 or 5 pounds *pressure* and 12 to 14 pounds of *vacuum* makes a tremendous waste of live steam by condensation, and a moderate vacuum and hot feed water use less coal to produce the same amount of indicated horse-power, other things being equal. We believe this position is tenable; however, it is a point for argument, and engineers who wish to do so may find food for figures drawn from actual experience, in case they take it up, putting any experience they may have in connection with the facts.

There is another point about this diagram which we have not elaborated on, that is, the reference of the area between the high-pressure and condensing, the relation of one to the other. The question is, does this engine do as well as though it carried steam a little further at a less pressure or not? There is not the least doubt that in many cases engines are underloaded, and, "to save coal," the condenser is added, and more coal used with a condenser than without it; the reason is not far to seek. A small quantity of steam raises the heat but little, and it is easier to maintain 14 pounds vacuum on a small amount of steam, and the cylinders are refrigerators to a greater extent than the point of economy.

LESSON LXXIX.

AN OLD CORLISS ENGINE, ACTUAL COST OF A HORSE-POWER PER HOUR.

In Fig. 161 we have a Corliss engine which has been running a number of years, twenty inches diameter, 60-inch stroke, sixty-three revolutions per minute, fifty-five pounds boiler pressure, throttle valve wide open, forty spring, Thompson improved indicator, not quite the whole amount of work on. Both ends are shown. We have made a demonstration only upon one end for the purpose of finding out how the engine was running. These diagrams were taken with a three-way cock, or by changing from one end to the other. In either case, we have demonstrated from the diagram coming nearest the boiler pressure, and it shows a beautiful working of steam, A line of boiler pressure, B atmospheric line, C vacuum, D volume of cylinder filled with steam at boiler pressure to do the work, cutting off at E, or at the intersection of the lines A, D. The theoretical line is dotted down to the point where it runs into the actual line of the instrument, which is considerable of a distance above the point assumed for the base line. It then follows so closely that we have used our old method again of dotting the intersection of the lines in the demonstration. There may be a slight difference in the terminal of this diagram, for the original was very faintly drawn and was traced over by hand. The steam line is extremely good on the right-hand diagram; the one on the left falls off considerably, and the pressure would seem to have changed between the time of taking the two ends. The vacuum in this case realizes about ten pounds. The diagram was taken August 4, and we could hardly expect much more than ten pounds, or twenty inches, at that time of year.

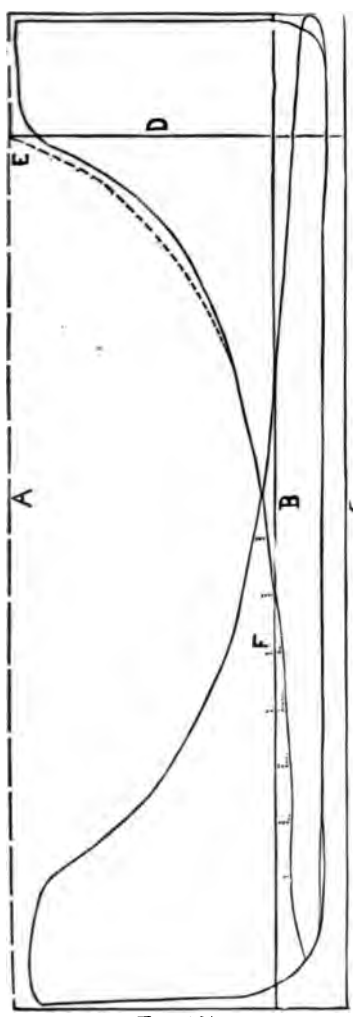


FIG. 161.

Taken all in all, it is an excellent diagram. There is in this case no leakage anywhere that we can find. The admission line, steam line, expansion, are all good. If we were to change anything it would be an earlier release and a trifle more compression, and it is possible we might obtain a little more vacuum by so doing. At the time of taking, a portion of the machinery of this mill was stopped. There are some figures accompanying this which will interest steam users. The power of the engine, four times per day, six days per week, averages 151-horse. The fuel used is three-fourths anthracite coal dust from city coal yards, and one-fourth Clearfield coal. The cost of this fuel is as follows: Clearfield $3.30, and anthracite dust $1.80 per ton of 2000 pounds, in the coal house; sixty-six hours' use, 17,110 pounds of dust, 5,622 pounds of Clearfield, making 22,732 pounds, costing $25.80; average power, 151-horse. The diagrams were taken twice in the forenoon, twice in the afternoon, and the average of twenty-four cards in the week taken for the amount of power. Pounds of coal per hour, 344; pounds of coal per horse-power per hour, 2.28; cost of 151 horse-power per hour, 00.39; cost of one horse-power one hour, .00259. Three horizontal, tubular boilers are in use, 6×16 feet.

Two boilers are used in the summer, three in the winter. The fireman is not allowed to use a slice bar any time during the day, but when the fires are banked at night they are cleaned. The inside of the chimney is equal to the full area of all the tubes in the three boilers, and 106 feet high, and the flue from the boiler to the chimney is a little larger than the full area of the tubes in the boiler. Ash-pit doors are never closed when the boilers are running. The mills started nearly two years ago, and the grates are as straight as when they were put into the furnace. The agent is a close student of the indicator, has profited by his experience, and bought a new Thompson Improved for his engineer, and, on condition that we will not refer parties to him, has given us permission to state the facts in connection, and also that his engineers and firemen are well paid, and take just as much interest in the economic handling of the engine and boilers as he does himself. We might, perhaps, say that this engine was wanted in a hurry, and was second-hand before it went into this mill, having been replaced by a very much larger one. It was overhauled, and this is its record.

NOTE.—The cost of an I. H. P., in anything but fractions of a cent per hour, should not be allowed; pounds of coal per I. H. P. per hour is a meaningless and indefinite term.

LESSON LXXX.

WHAT AN OVERLOADED CORLISS ENGINE CAN DO—SOME OF THE GENERAL DEFECTS OF ARRANGEMENT.

The diagrams with this are from a Watts, Campbell & Co. Corliss engine, and we have laid aside anything that is theoretical or supposed, taking only visible facts. And this shows one of the instances which are constantly coming to the notice of the engineer who has any indicating to do, of the necessity of simultaneous diagrams for adjustment of valves, or for reliable data with reference to power exerted.

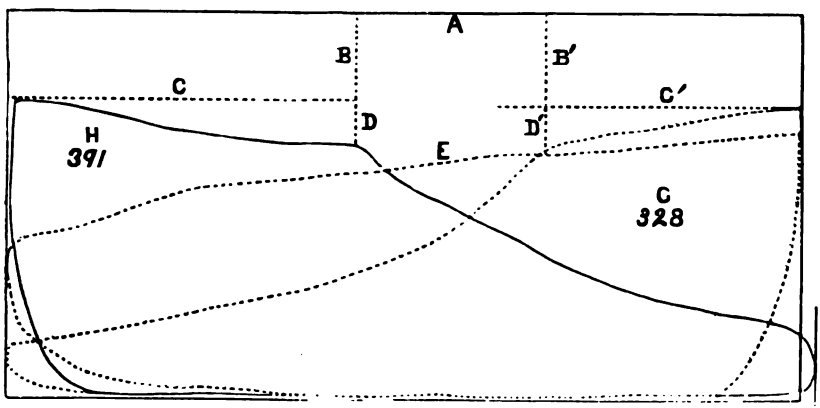


FIG. 162.

The diagrams in this case were taken on each end of the cylinder; A is the line of boiler pressure at the instant the diagram was taken, the scale being forty. B, B′ represent the visible point of cut-off, simply for comparison. C, C′ are the respective lines of initial pressure above the atmospheric line, or the instrument at rest. D, D′ show the lowest pressure from initial realized, and E shows what went on occasionally while one end was trying to catch up with or do as much as the other. These lines, simple in themselves, are full of meaning and will bear a little investigation.

The engine at this time was in the course of adjustment for the position of the valves to obtain the best possible results. The diagrams H and C were taken on the very same strokes of the engine, but we have not drawn in all the fluctuations caused by the reaching of the governor, first to increase for one end and then to diminish the cut-off cams' action for the other. We have here a boiler pressure of eighty-two pounds, a realized pressure of sixty-four pounds, a supply pipe of $2\frac{1}{2}$ or 3 inches diameter for a cylinder of 14×32

inches running 80 to 88 revolutions. The H end diagram in this case measures 391 on the planimeter, the C end measures 328. The line E occurred on every single diagram that was taken until after the two ends were balanced. In this case 391 equals 79.5 horse-power, 328 equals 67.6 horse-power, so that on a load of 80 horse-power we have a variation of about twelve horse-power between the H and C ends on the same stroke, or almost sixteen per cent. It will be noticed that the terminal pressure of the head end is seventeen pounds, the terminal pressure of the crank end is thirteen pounds, while the terminal pressure of the crank end when it makes a jump, as in the case of the diagram E, is 33½ pounds. The loss in the first place eighteen pounds between boiler pressure and the highest realized pressure on the head end. A loss is also made from the moment the valves open until they cut-off of ten pounds more on the head end, between realized initial and the pressure at cutting off, making twenty-eight pounds below boiler pressure, or a little over one-third of the steam pressure to start with on the expansion line. On the crank end a loss of twenty pounds between boiler and highest initial and eight pounds between highest initial and at point of cut-off. By a curious coincidence both ends cut off at about the same loss of pressure although at different lengths. The crank end carries steam equivalent to about 13½, as compared with the head end carrying 18, call it inches only for comparison. Most of these diagrams show the racing of the governor up and down with every stroke of the engine, endeavoring in every instance after the valve had been set for the head to get around quick enough to set the valve for the crank; in this case very wide variations were the consequence, and, in the particular diagram which we have engraved, only three lines were made in order to catch carrying steam at three-quarters stroke. Wherever more than four or five strokes of the engine were made upon the indicator card we find this carrying nearly full stroke on every one, so that about one line in four, or five, the regulator jumped to catch the crank end with the head end. Good engineers will understand this at once. The changing of the governor is continual and about once in so many strokes it will set a little further than is necessary and skip tripping the valve. All engineers will also see that this is an exceedingly dangerous practice; there is a great deal of force exerted as between 60 and 100 horse-power, when it is only for a single stroke of the engine, and something has to withstand that power or else the engine would smash.

There is another peculiarity in this case; it will be noticed that the crank valve is very nearly in position so far as the admission line is concerned, while the head valve shows plainly where the cushion terminates and the admission line commences; also that the admission line leans away to the right from the vertical line. This engine had only one screw in the jim-crank of the main steam valves, and the thread which connected the crab-claw with the iron stem was so coarse that a whole turn was too much, and nothing less than a whole turn could be given in adjustment, which is not the case with larger size engines. The eccentric having been put right for three valves, and the same difficulty existing on the crank valve, we were compelled to leave it a little

late on the admission line; for had we changed it again on the main rod, it would have thrown the crank valve just as much forward or backward, leaving us with only a whole turn to adjust with. This practice of having right and left threads on both ends of the exhaust and steam valve connections, to give nicety of adjustment should be insisted on by engineers in new engines.

If the readers will figure the pounds exerted between 79.5 horse-power on one end and 67.6 on the other, they will find that there is a very great change of force exerted between the different strokes and as many strokes as are made in each minute, which is not at all to the benefit of the engine. There are very many other points connected with these simultaneous diagrams, but leaving all but the practical, we find enough to encounter to draw our attention to the fact that it is very necessary to use both indicators, if we are getting either the power correctly, the variations in power or the position of the valves. It is an interesting study and more interesting in the practice. It will be noticed on the crank end that the exhaust is a little late on the small diagram, and that the same feature is very evident in the larger one. The small amount of power exhausts under a start of about five pounds, while the jump to nearly whole stroke exhausts under twenty-two or twenty-three pounds back pressure at the beginning of the return stroke. There are several interesting features which will be borne out if a little examination is given, and will prove all the more interesting.

This is one of the troublesome things to engineers, running from 50 to 100 H. P. regularly on a 60 H. P. machine. Some of the full load diagrams on this engine show 102 H. P., the builders did not apply the small feed-pipe, or arrange the engine to carry full stroke.

LESSON LXXXI.

AN OCEAN COMPOUND.

Figs. 163 and 164 were taken nearly three years since, from a then new ocean steamer; 163 is scale 32 per inch; 164, 12 per inch. The difference which is shown between the different ends of the cylinder show a trifle less than 300 horse-power difference between the left and the right-hand card. Taking A and A′ as the base lines, we find the point of cut-off at B, B′, from each of which points the theoretical line is drawn, taking the cylinder as realizing boiler pressure. The expansion line upon one end is somewhat peculiar,

but closely follows the theoretical with a little difference, which will be accounted for, as between realized and boiler pressure. Upon the other end we have a different account; the steam enters the cylinder and immediately falls away in pressure, so that at B′ ten pounds of pressure is lost between the initial and the point of cut-off, allowing six pounds for lost boiler pressure equivalent to equal to the other end. There is a reason for this. The left-hand card is from the top of the cylinder where the distance from the steam way to the indicator cock is less than one foot, while the other end is taken from the bottom of the cylinder through a steam pipe more than five feet long. It is probable that the left-hand diagram is much nearer the fact than the right-hand one, and that quite a difference in the horse-power would be developed if both these connections were made short, and two indicators, instead of one, were used. The release of this engine is very good. We find the commencement of exhaust on one end with 7 pounds receiver pressure, and only a trifle more than 7 on the other; the maximum pressure is 12 pounds. Quite a variation occurs in compression, and if the difference exists in proportion to the length of pipe connection that is shown in the compression on the two diagrams, then the left-hand diagram has a square steam corner, and the right-hand one comes honestly by the little hump at the commencement of the steam line. All these diagrams for that matter are only approximately correct, on account of this very crude way of establishing the indicator connections between the top and bottom.

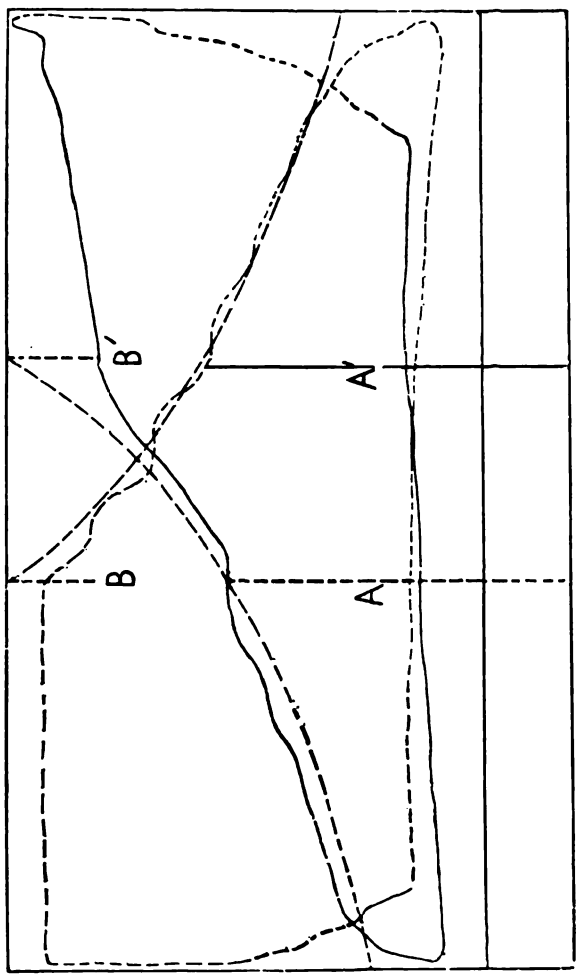


Fig. 163.

Turning to Fig. 164, we have a most peculiar train of circumstances. These diagrams were taken with a 12 scale. We have only drawn the theoretical curve upon one end, as that answers every purpose for comparison of the diagram. We first charge the engine with the full amount of receiver pressure, viz., 12 pounds; it will be seen that the opening of the valve is such that a little kick occurs in the opening action of the indicator. The steam line then falls off from receiver pressure almost 8 pounds. We have drawn the line D where the two steam lines of the diagram cross each other, and we find there a loss of plus 7 on one and about 8 pounds on the other end. But, to give the engine credit, we have drawn the line B on one side and B′ on the other as about the average of the realized pressure initial, and what the engine should have done if either end of the compound cylinder had have worked as well as the left-hand of the high-pressure. The line F is the line of the instrument, B is the line of initial pressure, C equals the volume of the cylinder filled or the point of cut-off, E the theoretical line drawn from the base line A. The steam in the cylinder if it had followed the line B up to the point C, and then the theoretical line would have yielded almost 200 horse-power more than it does do; the actual amount of the card shown is 1474.8 horse-power, while had it have realized the pressure B to the point C and the expansion line, with the same vacuum, it would have yielded 1662.9 horse-power. We find that neither end of the compound cylinder accomplished as much work as the high-pressure, and that there is a more radical difference in the actually developed power in the high-pressure cylinder, than in the low. The results in this case may be of interest to our readers. The steamship, from whose engines these diagrams were taken, made three round trips, the engines were very largely altered and very much improved, as they would need to be from the apparent action shown, from the very great differences which exist

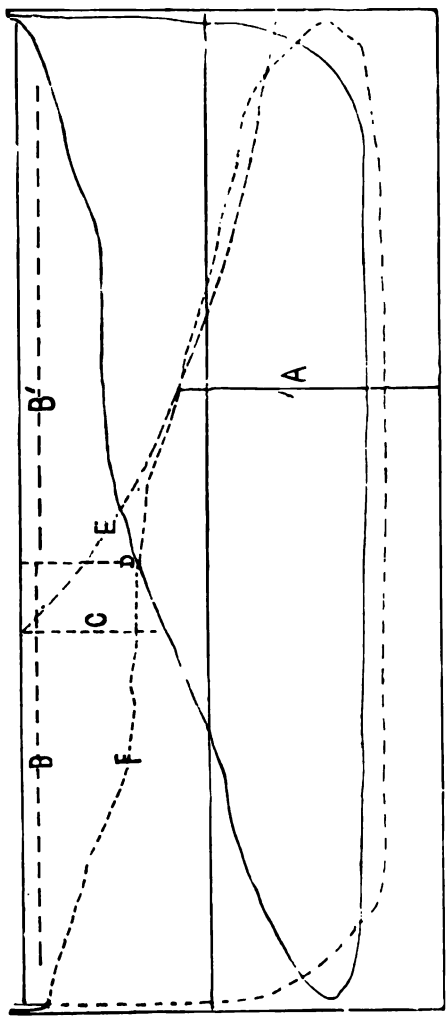


Fig. 164.

in both high and low-pressure cylinder, from first-class practices. These things are not visionary, theoretical, or supposable; it is only a matter of fact that they do exist as they do, and that it is so expensive a matter when such results as these are carefully figured out, to make a change in an engine, or abolish them entirely.

LESSON LXXXII.

DEFECTIVE CONSTRUCTION, AND AN INCIDENT IN THE USE OF THE PANTOGRAPH.

This lesson, with the exception of the Harris-Corliss diagram, shows radical defects in construction, in usage and in the application of the indicator, and it is quite as necessary that the readers of this volume should know where to look for difficulties and how to avoid them, as it is to know the theory of doing a thing right without having the practical results before them.

Figs. 165 and 166 were both taken from the same engine. The engine was of peculiar construction, and had been subject to several examinations and alterations, the warranty being, as is frequently the case, that it should equal the Corliss engine in economy, development and regulation. As the readers of this volume will have plenty of Corliss material with which to compare, they must form their own inferences or deductions, we have only to narrate the facts. The engine in question was built for a speed of 80 revolutions per minute; it was well located, well connected, but for some reason it had not given satisfaction to its owners.

Fig. 165 is an actual diagram with the simple addition of absolute vacuum, the base line and the theoretical curve, with a portion of the initial or realized pressure line added, in order to show that after the valve commenced to open, the pressure in the cylinder considerably increased, and instantly commenced to decrease perceptibly before the point of cut-off, which we have termed visible, occurred. The expansion line would seem to show a very fair action both of the indicator and steam, and without the theoretical curve, (with the exception of the joining of the admission and steam lines, and the little irregularities in that line as well as in the compression) it would seem to be a pretty good diagram. But when we apply the base line, to learn from it the point of cut-off and that one point of the theoretical curve quite corroborates the other with regard to the amount of steam used, it becomes less pleasant than on its first impression.

Fig. 165 was taken at a speed of 80 revolutions; the peculiarities of the diagram will be explained later. Fig. 166 was taken from the same engine during the same trial or observation, and at a moment when the speed of the engine had reached 124 revolutions per minute. The peculiarities in this are that the same general features which occurred in 165 are present, both in the compression and steam lines, and that the serrations or irregularity of the steam line is increased very much more by the high speed than it is by the usual speed of the engine. It will be seen also that the point of cut-off is quite different from that of the previous diagram, or 165, but that there still remains this extreme leak, and that both points on the theoretical line, initial and terminal pressure, corroborate the previous reading. Fig. 165 figures by the planimeter 10.1 horse-power; Fig. 166 figures 10.2 horse-power., at the different speeds at which they were running, at the moment of taking. It will be noticed that the steam line in both these diagrams shows almost a parallel line with the vertical at that end. This engine had been carefully examined by an old engineer, who had indicated it and reported upon it; the report was very favorable indeed. The facts in the case are as follows: The two diagrams, 165 and 166, show a variation of revolutions, 44, per minute; during the time of the

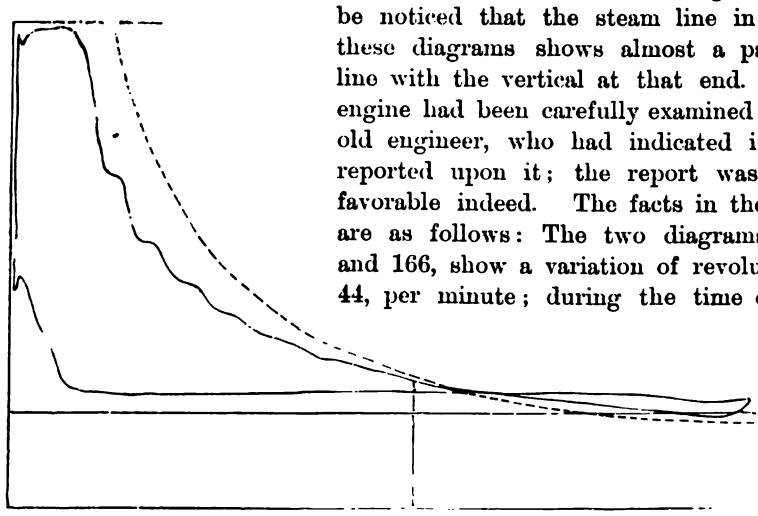


Fig. 165.

trial, the engine ran from 68 to 124, and there was connected with it an attachment for showing the variation in speed, which during the time ran completely off the paper band, without making the least mark; so much for the facts with reference to the regulation. During the time of trial, which extended over some thirteen hours, we applied the theoretical curve, and were somewhat surprised. When the finish of the test was made, the manager was called upon to make some examinations (which had been quietly made the night before, but without any proof). His attention was called to the fact that the piston traveled over the indicator plug holes at both ends of the cylinder, so that, as a matter of fact, the diagrams were perfectly worthless in regard to their steam lines and admission lines; the expansion line is, however, fully corroborated by admitting steam to the chest while the valves were unhooked from the eccentric, and such a jet of steam as came through the indicator plug holes has only been seen by those who have found valves which leak badly. In the case of 165, the steam line

approximates closely to a parallel line, but when the piston moves back so that the indicator hole is uncovered, the steam is admitted more and more into the indicator, giving a triflingly higher pressure just as the movement for the cut-off begins to take effect. The compression plainly shows that something goes on beyond it, and whatever amount of space may lie beyond that covered by the indicator hole we know nothing of, for no changes could be made, or we would promptly have made a clearance with a cold chisel or drill.

Fig. 166 shows the admission while the engine was racing, and simply magnifies what is plainly seen in 165 in a smaller degree. The expansion line in both cases, without the theoretical, would give an idea of a good line.

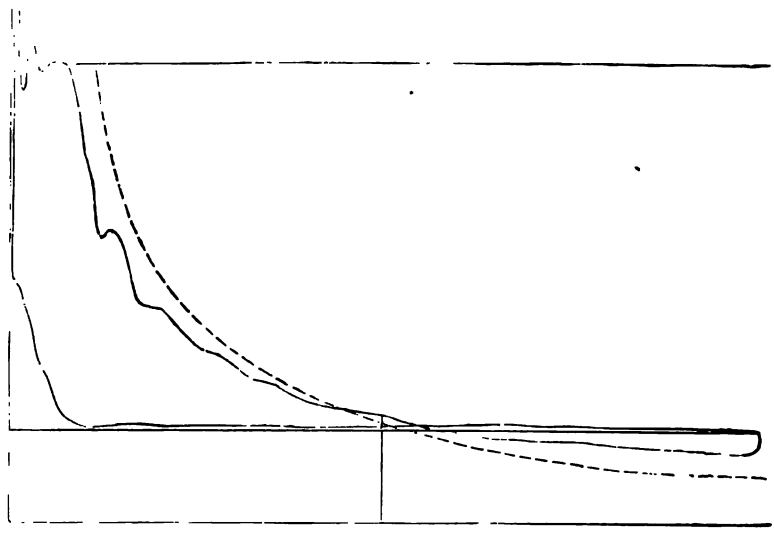


FIG. 166.

But, taking the actual pressure at the base line of the demonstration, we find there is entirely too much pressure for the steam and volume cut-off as by the visible point of cut-off on the diagram. We also find a corroboration of this in the fact that the theoretical line runs below the actual line, and the terminal pressure is as much too high in proportion as the absolute pressure is at the point of the base line. We were told some months after that the price of this engine had more than been paid by the damage it had done to the place it was working in, which would seem to corroborate the indicator's work to the extent of wasting the steam, and also the fact that the regulation was exceedingly far from that of the average-built Corliss steam engine. These two diagrams, 165 and 166, are well worthy the careful study of every engineer who desires to know something further as to the reliability of the indicator. Both diagrams were taken with a 30 scale.

AN INCIDENT.

Fig. 167 is from a Harris-Corliss engine slightly throttled, scale 40, and the only remarkable feature about this is the peculiar twist in the expansion line, something which very rarely occurs. This occurred a number of times while the author was busy in changing the valves, eccentrics, cranks, etc., and was really quite a puzzle until particular attention was given to what made it. The result of an examination proved that the cord which led from the indicator to the pantograph motion, which was being used, struck upon the top of the slotted screw next to the post to which our strings were attached, in such a way that a snap was given to the cord both ways, suddenly changing the speed of the paper barrel first above and then below, until this slot-headed screw, in the forward and backward movements of the cross-head, passed out of reach or control of the line of string. The pantograph was dropped a quarter of an inch on the post, and as much in the cross-head, and a long attempt was then made to repeat it, but it was no use. Both indicators were taken off and carefully examined. Nothing was found out. The pantograph was again raised to its original position, and the matter was repeated,

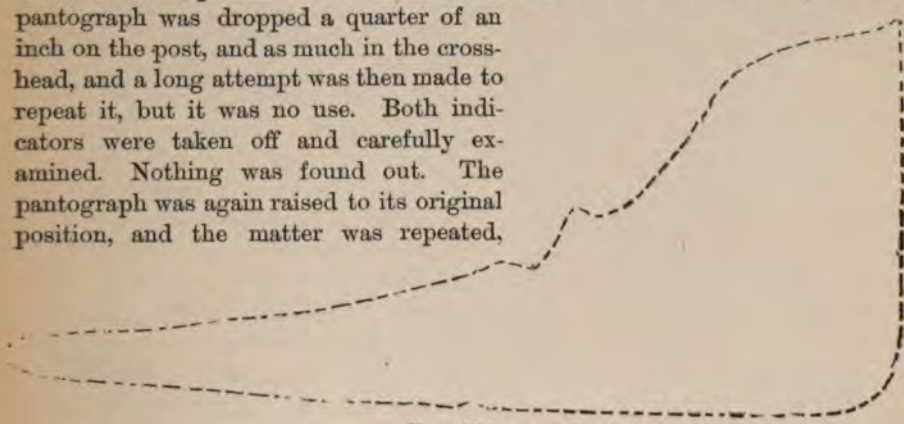


FIG. 167.

with variations, to satisfy us that this kind of an expansion line can be produced by snapping the indicator string by the movement of a nail, peg, or any other obstruction, across the line of the string. This same matter comes up wherever the pendulum is applied to any engine for the purpose of taking an indicator diagram. In this particular case the speed of the paper barrel was generally changed, first fast and then slow. The same thing occurs, although it is seen in a different way, and will be treated of hereafter, whenever the pendulum motion is being used, unless the sliding bar is used to communicate the motion to the indicator barrel. Whenever the pendulum is so attached that the motion is coincident with that of the piston, and is also exactly equal both sides of the center, very little variation will appear; but whenever the swing of the peg, or even an arc of a circle is used to communicate motion, the distance traveled is unequal distances on a straight line, while the speed of the motion may be uniform; the travel being upon an arc of a circle, it will give an unequal distance when applied to the travel upon the slides by the cross-head, and this varies the speed of the indicator barrel; and while it may be small in amount, it is suf-

ficient to make the expansion line entirely unreliable. This same point can be accomplished by boring a hole and putting a little peg, which has been slightly slotted on the top, with partly rounded sides, into the peg arm of the pantograph; but if the experiment is tried, be careful that this peg no more than strikes about one-third or one-half the diameter of the indicator cord, or a paper barrel spring completely smashed may be the result. This is an extremely insignificant point in some respects, it is the key to any motion that varies, or attempts to make straight travel by passing through an arc of a circle.

A CURIOSITY.

Fig. 168 is another experiment in steam engine building, scale 30. This was an engine used in grinding rubber. The cylinder was built with Corliss valves, while a different style regulator had been attached to an old bed, or the girder part of the bed. The several diagrams are only a small portion of the erratic movements caused by the changes in the regulator. The changes in the load were considerable, and the regulator would sometimes change from its highest to its lowest point on the very same stroke. Very little more can be said about this figure than that it shows a regulator utterly unfit to be used where any change of load should occur, and shows also that there is an exceedingly good opportunity for the engine to smash itself, in case of a sudden change from one load to the other, that was from the heaviest load to the lightest. On the other hand, if it was suddenly from light to heavy the engine would be exceedingly apt to stop. A, A, indicate the extreme ends of the atmospheric line of the instrument, and, in order to show the differences between the exhaust lines of the different diagrams, the atmospheric line is omitted. B, C and D show variations, the card intending to cover ten strokes of the engine, speed 80 per minute. It shows also that the engine is entirely insufficient in its port ways to exhaust under carrying steam two-thirds of the stroke. It shows in

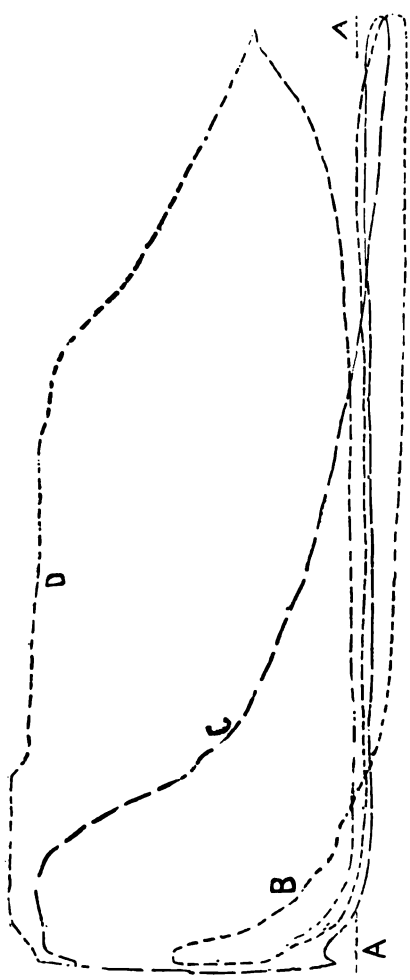


FIG. 168.

every case that the valves are a trifle late in their action, and the steam lines do not approximate very closely to a Corliss engine built by any of the builders who understand their business. In this case we have a pretty good cylinder with a very poor regulator, and an exceedingly poor showing of a Corliss engine for regulation, but it is a Corliss engine only in name, like many others, the improvements upon it make it practically worthless, or a departure from the real Corliss engine principles makes a departure from good practice and also from good results. These four diagrams cover an amount of information which will only be measured by the patience that the persevering reader shall give to them, and the benefits which he will derive will only be measured by his acuteness and careful attention, and if these are given many engineers will be saved trouble or being humbugged by any attempt by parties who are interested in the sale or attempted misrepresentation of the actual working of machines. Excepting 167, these should all find their way to the scrap-pile, and cease to be an annoyance to the engineer in charge, as well as to the men who supply steam and fuel for their running.

LESSON LXXXIII.

FOR THE BEGINNERS.

During the four years which have elapsed since the first systematic course of articles upon the indicator first appeared, the author has found very frequent inquiries for the elements, as men were continually taking up the indicator to learn something of it, who had not seen the first series of articles, and consequently had omitted many little points which are essential to men who have never held or handled the indicator; to such ones this lesson is especially adapted, while it will not do the older ones any harm to occasionally run over it in order to obtain other or more information and frequent reference to something about which they may have doubts. The indicator is intended not only to measure correctly the proper power exerted, but it also gives us, if correctly applied, the manner in which the valves handle the steam; it tells us of the position of the valves with regard to the stroke, whether the motion of the valves is sufficient or not. It also tells us whether the ports, passages, throttle valves, steam pipes, exhaust pipes and ways are all sufficient, or, if insufficient. It is not able to tell the particular point at which the trouble is, but it will give the trouble, and then we must find

its exact location. It frequently shows us that feed-water heaters are an element of trouble by the insufficiency of the area of the steam passage allowed for the exhaust steam. Sometimes it will tell us of a leak in valves, or of many little points which are not necessarily to be particularized here, so that to cut the enumeration of all these things short, the indicator will tell us at any time, if honestly applied, when the engine is working correctly or incorrectly; if incorrectly, it will show whether there is back pressure, too late release, too tardy admission, throttling between admission and expansion, whether the engine is overloaded, or any of these numerous happenings which can be found in item and detail by the previous lessons in this book. Directions have already been given for computing; any one can do this, who chooses to give a little time to it.

Now the standard in all cases is the ideal or perfect diagram. The perfect steam engine (which has not yet been built) is expected to economize

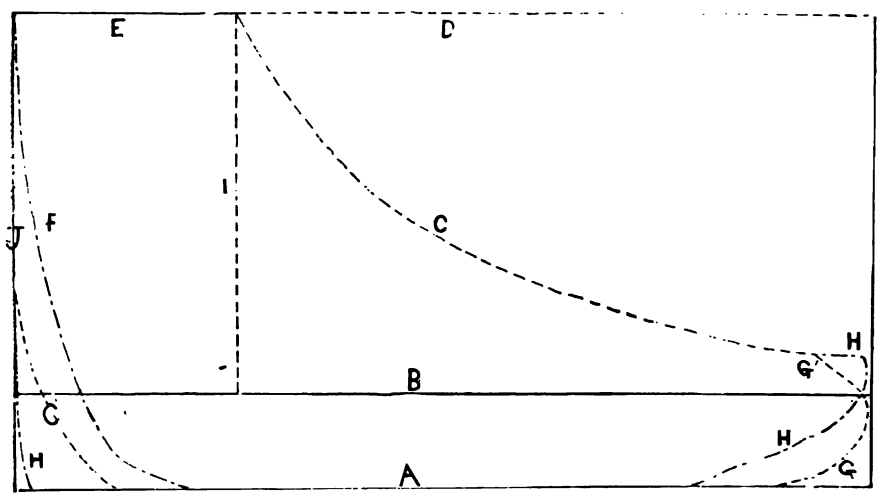


FIG. 169.

by the use of full boiler pressure, to cut it off sharply, expand it theoretically, release it early, exhaust, if non-condensing, at the atmospheric line, and if a condensing engine, we are expected to accomplish about 14 pounds of vacuum (theoretically 14.7 at the level of the sea) to compress slightly according to the fancy of the builder or the engineer, and in this way to realize all the heat units and the effective pressure upon the piston, and in that way make the coal consumption reduced to the minimum. The steam engine cannot, however, go back to the steam boiler and rearrange inefficient furnaces, too large or too small steam space, or any of the thousand things which may go towards making an incomplete, insufficient, or badly arranged boiler plant. The engine is expected to take the steam pressure in the pipe and use it in the most economical way; for that reason, we have constructed in Fig. 169 the generally-accepted theoretical diagram. It is made upon a

scale of 30 to the inch, having 60 pounds steam pressure and 14.7 pounds or absolute vacuum. The various lines to which frequent references have been made in this book, are as follows: A is the absolute vacuum, which differs with the barometric reading, and we have laid out the vacuum for the level of the sea; B is the atmospheric line of the instrument or *the* line at which the pencil point of the indicator rests after having been thoroughly heated, after allowing the steam to come in contact with the piston and working parts of the instrument, and then shut off all steam connections. And here it is well to take notice of a little point which may have been omitted; when the indicator has been attached, the motion arranged and the cord or wire connected, turn the steam gently upon the spring, heat the instrument thoroughly, and not until this has been done, should the atmospheric line be taken; having done this, now be extremely careful never to allow a particle of steam to escape from the three-way cock while taking the atmospheric line, for if you do, you will distort the line, making it too high or too low; D represents the boiler pressure, and is dotted from the point of cut-off E, I, the rest of the length of the diagram; E represents what is usually spoken of as the steam line, or that portion of the diagram made between the time the valve is opened and that portion of the piston travel that the valve is held open; the dotted ordinate, I, dropped from E shows the point at which the cut-off valve is supposed to have positively closed, and C represents the expansion line from the point of cut-off E I to the point of release G′. We will digress for a moment. Such a steam line as we have drawn in Fig. 169, E, will not be found one time in thousands, the reason for it is assignable to a great variety of causes, which may be changed materially by either of the following; by inattention to the correctness of the reducing motion, and insufficient steam ports, steam passages or steam pipes, or too small a throttle valve, to an ill-proportioned travel of the valve with reference to the piston; wherever any of these reasons operate, this line will be modified in any of a great many ways which are shown in the preceding lessons, as well as in Figs. 170, 171. The expansion line C partakes of a great many variations. It is exceedingly rare that we find one that approximates very closely, and for this there are a great many different reasons; the distortion of the motion, any error in the travel or capacity of the valves, any leak in the valves, which may be very trifling, will make a difference in this line. Leaking by the piston, the presence of water, to which is added the variable speed of the piston, or expansion, diminution of pressure, increase in volume, a change in the physical properties of the steam, and if the indicator itself be not in perfect working order, the expansion line is likely to be an erratic one. The theory upon which the expansion line is based is that of Mariotte's law, that increasing the volume diminishes the pressure in a certain known ratio. This from the very nature of the thing, has never been definitely proved, but the general foundation of the law is that as the volume doubles the pressure decreases one-half, and so in proportion. At G′ the continuation of the dotted, like the expansion line C, has been drawn at an angle rather sharper, perhaps, than the general construction of engines will admit of in release, by the actual lines of the indi-

cator, but we have drawn it thus distinct, for the working engineer has frequently an idea that he should not release until he had obtained everything that was possible out of the steam. Here is a point of practice about which some engineers now differ, but those with the largest machinery and the broadest practice, have no doubt and no difference, viz., if we commence our release at G', following the line which shows a rounding into the condenser at the extreme end of the stroke by a full open valve, we shall then continue the line G below the atmospheric line, so that it reaches the full extent of the vacuum at about one-tenth of the stroke; and if the exhaust valve of an engine—taking the Corliss as standard, or any other well-constructed engine—opens a little before the end of the stroke in order to release the expanded steam as soon as possible, and allow the condenser to have full swing at it, we shall close that valve as much before the end of the stroke on its exhaust as we open it before the end of the stroke, provided the builder of the engine has properly proportioned the travel of the valve. As we are working on an ideal card, we shall suppose we are dealing with a first-

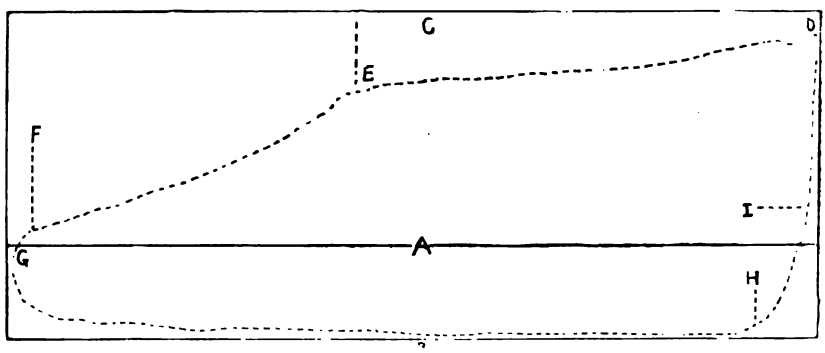


FIG. 170.

class builder so that the distance from G' to the end of the stroke, will give the condenser a wide open valve at the very commencement of the return stroke, and will immediately reduce the steam to full vacuum at the intersection of the lines G A from the terminal pressure end of the diagram, and will make the dotted compression line G, touching the vertical line J at about 17 pounds above atmospheric pressure. There is a great difference of opinion among engineers, some claiming that it is impossible to compress upon a condensing engine. This is a mistaken idea, and, while many prefer to run their engines without any compression, they will find, if the engine is properly constructed, that compression within a reasonable limit is invariably an advantage, because, if we take the line G as an instance, we have 17 pounds above the atmospheric line of pressure at the very end of the stroke; if, now, the steam valve is properly set, so that it commences to open and continues the dotted line G, from its intersection with J, following up the line J, by what is known as the admission line, we shall then have 17 pounds pressure in that end of the cylinder upon which we put enough

to bring it up to 60 pounds, while, if we do not have any compression, we have to put 60 pounds instead of 43. We have now completed the circuit of the diagram; upon the same diagram, 169, notice the irregularly dotted line H (which is the most usual line of compression) in which the steam is carried beyond the point G′, by means of the dotted line H, which is differently dotted from G′, and where the steam pressure is confined until almost the extreme range of travel of the piston, barely commencing to open at the very end of the stroke, in which case the irregular line H is continued and shows the effect of a later opening, so that the absolute vacuum is not obtained until the piston has traveled twice as far on its return stroke, or about one-fifth of the whole stroke, as it did with the earlier release at G′. As the motion of the valve here is later, so it will be later in closing. The line H is supposed then, from the point of its intersection with A, to travel from the line A until it reaches H, where it will be found to extend but little above the atmospheric line, making only a pressure of eight pounds. The general practice on condensing engines is that wherever the late opening and late closure are practiced, that it is much more frequently followed with 7, 8, 9, or 10 pounds of vacuum instead of 14.7. The earlier the release consistent with proper compression, the larger amount of vacuum is obtained from the same amount of steam. The later the release, the later the compression, and the less amount of vacuum is generally obtained, but as all classes have their ideas, and we take diagrams from all descriptions of adjustments, we have thought best to introduce here for the beginner's benefit, the long dash and dotted line F, which shows a very general idea of excessive steam lead, joined to a considerable compression. This line may be made either by excessive compression or by a steam lead; and by steam lead we mean just this, that the compression took place from the absolute vacuum line A, and the steam valve opened considerably before the piston arrived at the end of its stroke or the dead center. This line will be frequently found upon modern constructed engines where an attempt at high speed has been made, but it is not desirable. The difference between excessive compression or steam lead, and correct compression is simply this, if the valve is shut before the exhaust is complete, or slightly before the piston arrives at the end of the stroke, a small amount of low tension steam is compressed gradually to a higher pressure, and consequently to a higher temperature, and it offers mechanically a "cushion" upon which the piston gradually strikes, and it comes to a more gentle stop than as if nothing were there, when there would be a certain amount of strain upon the gibs, keys and connections, if the cushion were not present; and with the cushion an amount of steam is saved, and the wear and tear on the connections of the piston rod, cross-head, connecting-rod, crank-pin is reduced.

For any variation from the ideal diagram there is always some reason, and the beginner or the man who has had practice, should aim to obtain the most perfect results that are possible, and, in every instance, to investigate every departure from the theoretical, unless, as in some of the instances given, the simple outline of a card shows an exceedingly faulty construction;

and it is sometimes well for a person who has not had much experience to study these very faulty cards for his own benefit and future reference.

With a view to some contrast we have introduced Fig. 170, which is from a Corliss engine, overloaded and throttled, or choked in the steam supply. Referring to this figure (170), A represents the atmospheric line of the instrument, B absolute vacuum, C steam-boiler pressure, D highest initial pressure realized, which is only 33 pounds out of 38. The steam line from D to E, supposing E to be the point of cut-off, shows 8 pounds less steam pressure at the point of cut-off than at initial. This is caused by the feed pipe being too small, and contrasts strangely with the ideal line E in Fig, 169. The point of cut-off at E, 170, will be seen to have been rounded over, which is caused by the slow closing of the valve, and the expansion line in this case may proceed closely on the theoretical line, if he can find the exact point of cut-off. F is the point of release or evident opening of the exhaust valve, and

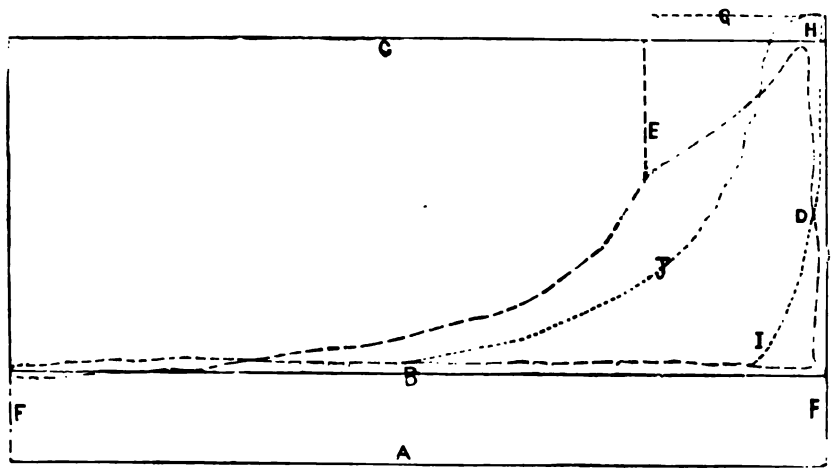


FIG. 171.

G is the commencement of the vacuum, and it will contrast very strongly with the ideal line in Fig. 169, as shown, and in this case (170) the engine runs back to nearly one-third stroke before the maximum amount of vacuum is obtained. At H the compression commences and closes at I above the atmospheric line; while the steam line from I to D, Fig. 170, shows that the valve commences to open very slightly before the piston arrives at the extreme end of its stroke.

In Fig. 171 we have another type of very frequently-found trouble which is more marked in this case from the fact that it is from a Corliss engine. Many engineers have an idea that they must invariably get an engine under motion with a partly closed throttle valve. A Corliss engine that will not start with a throttle valve half open or more, is decidedly out of adjustment. In this case we will not, however, discuss anything except those points which the learner most frequently desires to have thoroughly fixed in his mind. The

coarsely dotted diagram, if we start at the point D, shows that the steam valve opens too late; at the top of the line, directly under the letter H, it will be seen that the steam line leans to the left, or away from the vertical line F. The peculiar shape of the steam line, from H down to E, is caused by the throttle valve being so nearly closed that steam enough is not furnished to keep the pressure up to the line of realized pressure C; consequently the cut-off valve is held open for a greater proportion of the stroke than would be were the throttle valve wide open, in which case the pressure C would only be realized. At E we find the visible point of cut-off, or near enough for practical purposes, is 21½ pounds below the pressure at H, while the expansion line runs below the atmospheric, making a loop. This loop is, in all cases, resistance, and should be so figured in computing the diagram for power. If we follow the exhaust line on the return stroke of the piston, we find a square corner at the terminal of the exhaust, and the steam line commences, leaving the vertical line F more and more, which shows that the opening of the valve is entirely too late. The fine dotted line shows the eccentric rolled forward on the shaft to bring the steam line from the point D up to the vertical line F, or so that the valve commences to open and admit the steam as soon as the engine gets upon the dead center. It is a fact, that whenever the valve is late in its opening, the pressure of steam is invariably reduced, and the later the valve is in its opening, the greater the reduction of realized pressure. In this case, after the eccentric has been thrown forward to bring the steam line proper up to the vertical line F, which is at right angles to the vacuum A, and atmospheric B, as well as the realized pressure in the first case, C, it will be seen that the realized pressure on the piston increased nearly five pounds, or to the line G. In this case the throttle valve is wide open; notice the beauty of the expansion line J, which we have only drawn until it reaches the exhaust line at about the point B. This would make decidedly more of a loop than the coarser dotted diagram, but in moving the eccentric forward we have also accomplished another very important and economical point, which is the compression. Notice the fine dotted line I, which compresses the steam 23 pounds to the point D, at which point the steam valve commences to open and fills the cylinder with steam the balance of the 56 pounds. Both these objects, viz., opening the steam valve at the proper time and closing the exhaust valve quicker, are accomplished in this case by moving the eccentric about three-quarters of an inch of the circumference of the shaft forward. Sometimes when this is done we may throw one valve exactly up to the right point and the other one may be too quick, or to give too early a steam line, and it may affect the exhaust valve or compression and release in the same way. Get the steam valves right by means of the jim-crank connection, and on the Buckeye engine, get them right by the compensation arrangement on the valve rod, by which you can divide the travel of the valve, or any difference in the travel to the hundredth of an inch. In the Armington & Sims engine this is usually done at the shop, but in case of tinkering or changes, take off the valve chest cover, and move the check-nuts on either end of the valve until you have it exactly where you

want it, and whenever any changes on the engine are made in this way, pay no attention to prick-punch marks, cold-chisel slashes, or anything of that sort, work by the lines of the indicator, taking care that they are perfectly correct in their motion, corresponding to an absolute reduction from the travel of the piston. In this way no difficulty will be found in adjusting the valves of a Corliss engine to an exactness that will give a small fraction of a horse-power difference on a large engine between the ends.

On some of the slide-valve engines, it is exceedingly difficult to balance, for we frequently find the travel of the valve not correctly calculated, in which case we must work for the best good of most of the factors in the combination. Sometimes we have to sacrifice a little on the steam line for the sake of being sure of a good release, and at other times we get a release without compression for the sake of admitting the greatest amount of pressure.

But there are other methods of attaching the indicator which are very valuable. Fig. 172 shows two different diagrams taken at different times,

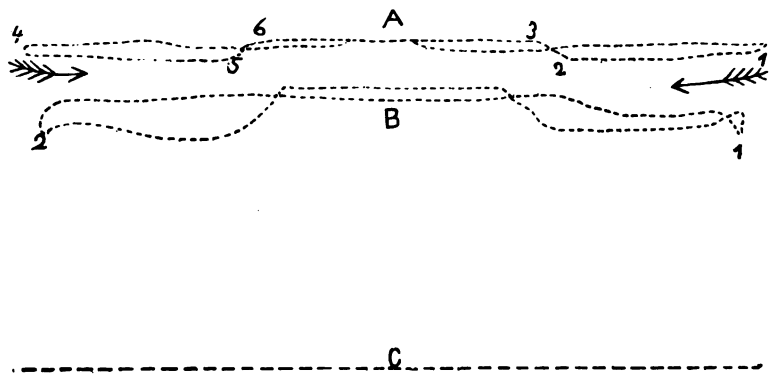


FIG. 172.

but both for the same purpose. These are what are termed steam-chest or steam-pipe diagrams; they are taken by attaching the steam engine indicator to the steam chest where possible, or to the steam pipe below the throttle valve, and connecting the indicator with the same motion by a separate cord (taking pains that no angles except right-angles are made) with which the indicators at the end of the cylinder are driven. Care should be taken to make the steam pipe diagram of the same length, as nearly as possible, with the diagram from each end of the cylinder. In that case the proportions between them are precise, while in the case of a longer or shorter one it requires figuring to learn their proportions.

Fig. A, 172, was taken in 1868 from a Harris-Corliss engine, scale 30, to ascertain what proportion of boiler pressure was realized, and a little study of the diagram will satisfy any engineer that these steam-pipe or steam-chest diagrams are quite as valuable as those taken from the end of the steam cylinder, and frequently they give us a clue to what occurs before the steam

reaches the steam chest, so that we may not pull the engine down but rather pull down the pipe and go back to find the trouble. If we start at figure 1 and follow the line in the direction of the arrow to 2, we find that the pressure in the steam chest is slowly diminished, while the valve at that end of the cylinder is held open, and this distance from 1 to 2 shows the exact distance that the valve was held open, or until it completely closes, in feeding the cylinder with the amount of steam allowed by the position of the regulator cams at that instant of time. The valve commenced to close at 2 and the pressure gradually increased up to 3; the valve was at that time fully closed and the pressure ran along to just beyond A, where the pressure dropped slightly by the draft of steam in the pipe. At 4 the other end of the valve opened and steam was carried from 4 to 5, at which point the valve commenced to close and made a more abrupt closing from 5 to 6 than from 2 to 3.

This diagram in itself is one of the finest we have ever taken, and if carefully taken, they tell the action of the steam in the pipe, precisely how far steam is carried on the cylinder, when the valve opens and when it closes, and every fluctuation of pressure which occurs in the pipe from beginning to end. Fig. B, 172, is from a Buckeye engine, at the American Institute Fair in New York, taken in November, 1884, scale 50. This engine was running from 222 to 225 revolutions, and it presents a contrast to the other diagram, from the fact that a large amount of compression was shown upon the right-hand end and a moderate amount upon the other. At figure 1 the pressure falls with the opening of the valve in the steam pipe, is immediately raised by too much compression, and this occurs while there is but a very slight movement on the part of the piston toward the completion of its stroke. The steam pressure is then led off by the opening of the valve, toward B, falling off very little indeed. It will be noticed that the curve on the Buckeye engine, formed by the closure of the valve, is somewhat longer than that on the Harris-Corliss engine from 2 to 3. The Buckeye uses the slide valve, the motion is slightly slower, although it is very fast. We then reach the highest limit of pressure. On the other end of the engine, at the commencement of the stroke, or opening, the pressure slightly diminishes, holds steady for the first half of admission and then the pressure slightly falls away, until the time of the closing of the valve. Both diagrams are very fine and show the difference in practice between the valves; C in both cases represents the atmospheric line. When these steam-pipe or steam-chest diagrams are of exactly the same length as the cylinder diagram, they are exceedingly useful, and they should be taken from every engine that has indicator connections or attachments.

Another good place for the indicator to be attached is to the exhaust pipe between the engine and the heater, or between the engine and condenser. Care must be taken, however, in the case of a condensing engine whenever the indicator is to be applied, never to turn the three-way cock so as to break the connection between the condenser and steam engine cylinder. In the case of a condensing engine, we can frequently find where a

part of the difference between the vacuum gauge and realized vacuum is accounted for; in the case of a high-pressure engine we frequently obtain from this a back pressure of from one-half to two or three pounds, and in cases where the steam is returned or changed in its direction through the feed-water heater, we sometimes find that the heaters have not the same area in their tubes as the exhaust pipe has. All of these things the indicator is perfectly applicable to, and with proper connections will be found of great value, or quite as much so as in the case of the cylinder itself.

It is also interesting to indicate steam pumps or water pumps, as we sometimes get a very curious record of the operations which go on inside a cylinder, to show us that the pump throws well one way and not well the other; and it is often to our advantage to examine these things, for we may find the valves on one end of the pump seriously out of order, and in that way avoid trouble in case of fire, or when the pump is called upon suddenly to do its utmost work. In some cases of steam-pipe throttling, it is well to have diagrams taken from different parts of the pipe (the motion can be readily transferred to almost any distance by using carrier pulleys) and in this way we frequently locate troubles, where nothing but taking down a large steam drum or main steam pipe would allow the object to be accomplished otherwise.

It is well for the beginner to also practice somewhat with different motions, to ascertain which are correct and which are incorrect. Get the length of your travel on the diagram on the paper cylinder, then divide this into four equal parts, or into as few or as many parts as you choose, turn the engine over carefully, and, if you are using the pendulum, you will soon find that you cannot make a peg, traveling the arc of a circle, conform to the exact divisions of the travel of the cross-head on the paper cylinder.

Another point, which frequently makes trouble for beginners, is the deducting the piston-rod area from the effective area of the cylinder. The crank end of the engine has the size of the piston rod to be deducted from the area of the piston; beginners sometimes are troubled by not knowing whether this should be taken from both ends, or from one end. It can only be taken from the end that it exists on. If we have a piston 30 inches in diameter, and a piston rod 3 inches in diameter, we take the area of the 3-inch piston rod from the area of the 20-inch piston; the difference is insignificant, but the beginner may as well figure it for a few times and ascertain that it is an almost unimportant factor, unless in the case of steamship engines, where we sometimes have a piston 120 inches in diameter, with a trunk varying from 36 to 50 inches; it then becomes an element of very great importance. A great many hints as they occurred in practice, will be found in the various lessons preceding this, and they can only be properly studied by carefully studying each lesson by itself, for they are best remembered when the circumstances under which they occurred, are recorded.

LESSON LXXXIV.

WATER PER HORSE-POWER FROM THE DIAGRAM, OR STEAM CONSUMED.

It is very frequently necessary to make a computation either upon the amount of steam per horse-power, or the amount of water per horse-power accounted for by the diagram. These matters are to a certain extent complex; not, however, from necessity or reality, but because they have frequently been made to appear complex by the amount of figures incorporated into them. All computations, as we have stated, must be from the absolute vacuum, for on that line is founded the temperature, volume, weight and other properties of steam. The reader of this volume will by this time have become familiar with the reasons why this base line is assumed in every case as the only basis of actual comparison. If we wish to ascertain the amount of steam consumed from the diagram, or, as it is frequently termed, steam accounted for by the indicator, we take the absolute vacuum at 14.7 below the atmospheric line of the diagram. For real correctness the clearance of the engine must be known, and this amount, the clearance, should be added to the diagram on a scale equal to the scale of the diagram. If the diagram is four inches long and represents a stroke of four feet, five feet, ten feet, or twelve feet, it is easy to ascertain precisely what any fraction of the four inches represents proportionately. Add to the diagram of the indicator the clearance, if you can, and this clearance must include the cubic inches between the piston and the cylinder head at full stroke; also, the exhaust port to the face of the valve, and the steam port to the face of the valve as well. It is usual to figure the amount of steam consumed, or accounted for, from the point of release. This is not necessary, and sometimes it is absolutely impossible, to tell precisely where release commences. Take any point on the line, either at the point of cut-off, or on any point of the expansion line before the exhaust valve opened. Now take the length of the stroke, including the clearance, up to the point where the pressure is measured, and from which point the computation is to be made. Multiply the length of the stroke to that point by the area in square inches of the cylinder; this will give you the volume of the cylinder to that point, and to this amount must be added the number of square inches of clearance up to the point of the computation, this gives the volume of the cylinder; multiply by the pressure to the point of computation; divide this product by 14.7; this quotient gives the number of cubic inches of steam at the pressure of the atmosphere discharged from the cylinder at a single stroke, or to that point of the stroke where the pressure is taken. If there is no leak in the valves, and the steam is not saturated with water, the cubical contents of the cylin-

der multiplied by the pressure at the point of cut-off should exactly coincide with the cubic contents multiplied by the pressure at the actual point of release. If both cut-off and release are well defined, it is a good plan always to make both these computations, and it will frequently be found that the point of release gives the greatest amount. This at once shows a leak. In a compound engine the cubic contents of both cylinders should agree with each other, if the computation is made in this way from the points of release in both cases. Having reached the cubic inches of steam at the pressure of the atmosphere, multiply this by the number of strokes in an hour, and don't get confused, you are working upon one side of the piston only; take care that revolutions are not considered, for in the one case you will get double, and in the other half the actual result. Having multiplied by the number of strokes in an hour, or the number of times that end of the cylinder is filled with steam in an hour and exhausted, divide this product by 1728, the number of cubic inches in a foot, in order to reduce cubic inches to cubic feet. We have now the number of cubic feet of steam used per hour. divide this by the indicated horse-power of the diagram and you have the cubic feet of steam per horse-power per hour. If the amount of water used or accounted for is required, divide the number of cubic feet of steam per hour by 1700, this gives the cubic feet of water used per hour. If pounds of water are wanted, multiply the last result by 62½; or, if gallons are wanted, divide the product by 8.33 pounds for wine gallon. Care must be taken in making these computations to get at the average or actual power required. It is hardly possible for the indicator to account for all the steam consumed or all the water used, for as a matter of fact any excess of leakage, or any change of circumstances, such as blowing-off, will require a larger amount of water in the boiler than the indicator can account for; the indicator simply accounts for what is used at and in the engine, and the indicator cannot account for leakage from any cause.

Or, to repeat the formula in a different way, without the explanations, obtain the volume of the cylinder to any point which is perfectly plain, between the point of cut-off and the point of release; this is in cubic inches, and must be multiplied by the pressure at the above point from the vacuum; then divide by 14.7, the pressure of steam at the atmospheric pressure, this gives in cubic inches the amount of steam discharged at each stroke. This quotient is multiplied by the number of strokes or times that the cylinder is filled at one end per hour; this gives the total number of cubic inches of steam accounted for by the number of strokes which are made in one hour; this is reduced to cubic feet by dividing by 1728, which gives cubic feet of steam. Divided the cubic feet of steam by 1700, the volume of steam at atmospheric pressure, and the result gives us cubic feet of water; multiply this last result by 62½ and we have pounds of water; this divided by the horse-power gives us pounds of water per horse-power for one hour.

ANOTHER METHOD OF COMPUTING THE WATER PER HORSE-POWER PER HOUR.

The volume of the cylinder multiplied by the number of strokes per minute, multiplied by 60, or the minutes per hour, divided by 1728, gives cubic feet. Multiply the last result by the weight of a cubic foot of steam at the pressure at the point of cut-off—or the point from which the computation is made, using the pressure above absolute vacuum—and divide this last by the horse-power, and the final result will be pounds of water per horse-power per hour. (See table of "Properties of Saturated Steam" for weight of one cubic foot in decimals of a pound.)

VACUUM.

TEMPERATURE AT DIFFERENT "POUNDS PER SQUARE INCH" AND "INCHES OF MERCURY."

The very peculiar position in which we are placed in using one or the other of the thermometer scales, now generally in use or cited by scientific men in experiments, or in contrast or comparison of results, makes an enormous amount of trouble and bungling by comparing all others with the Fahrenheit scale which commences on an assumption over 300° from correct and ends in a guess, or, as Mr. Porter has so aptly said, "begins in a blunder and ends nowhere."

Fahrenheit assumes 32° as freezing, and 212° as boiling. Centigrade gives 0° as corresponding to freezing on the F. scale, and 100° on his thermometer to boiling, or 212° on the F. The general adoption of the Centigrade scale for scientific purposes, at home and abroad, should be much more general, as the F. does not commence with fact or continue with accuracy.

TOTAL HEAT.

There is no term used which is more of a misnomer. Absolute cold has been determined with all reasonable certainty as 459° to 461° below the arbitrary point as assumed by Fahrenheit, so that in the tables of all scientific works "total heat" is a false application of a term, notably in some of the literature which has emanated from the United States Bureau of Steam Engineering, and total heat expresses only from Fahrenheit's assumed zero.

INCHES OF MERCURY.

Usage has confirmed the use of a scale as rude as the tally stick of ball players in our younger days, when notches were cut in a stick with no graduation or calculation, simply guessed at. The English government have adopted at the Royal Arsenal at Woolwich, mercurial gauges based on equal divisions from the "standard of usage," that 15 pounds to the square inch equals 30 inches of mercury, and the curious feature of these "standard" gauges to us, on examination, was the fact that each pound pressure coincided with *even inches.*

The expansion of mercury for each increase in its temperature of one degree F. equals .00100854.

The starting point is, mercury at 32° F. equals a volume of 1, and as the changes in temperature occur—if mercury is to measure the changes—then we must correct the column of mercury for the degrees. Hence it follows that inches of mercury do not follow any assumed or empirical scale of equal inches, and when so combined neither element shows a correct reading.

One pound pressure in inches of mercury equals 2.037462+ inches.

The specific gravity of mercury is 13.595+.

Water is at its greatest density at 39.2° F. or 4° C., and M. Regnault has brought out some curious facts in his elaborate experiments on air, water and steam; and these are so extensive and so valuable that all persons who study steam should have them at hand.

He has determined that saturated steam cannot be investigated separately on account of "the expansion and contraction of its volume consequent on changes of pressure, and those consequent on temperature, because at the same time its volume is being contracted under increasing pressure, its expansion takes place with increasing temperature," so that the density of saturated steam is an unsolved problem, and Mariotte gives us data approaching exactness from formulae of air, which, under a constant pressure doubles its volume on an increase of temperature of 272.8° C., or 491° F., and in temperature of steam a confusion exists at the same pressure by different authorities, and frequently some unexplained feature exists which may be the point from which they start out, and we have to ascertain this point and add or subtract 32°, or some other number, frequently, in order to reconcile the data given.

The Density of Steam is 1, divided by the volume at any given pressure, and at the atmospheric pressure the volume is 1702, so that the density becomes the fraction $\frac{1}{1702}$ that of water at same pressure.

TEMPERATURE OF VACUUM.

The following table is from M. Regnault by transposition, and shows the pounds per square inch. The temperature and the inches of mercury corrected for temperature. The temperature is given by each 4° F., and the

fractions are closely as possible expressed in three places in the first column, and four places in the third column.

The unit of heat being the heat required to raise the temperature of one pound of water 1° F., if we require to compute from any point; the heat contained in the water from the starting point, 32° F., must be subtracted from the heat given, and we can then convert into steam from and to any pressure, from any of the tables in this work:

Pounds per square inch.	Temperature.	Inches of Mercury.	Pounds per square inch.	Temperature.	Inches of Mercury.
1.127	208°	2.3028	13.182	116°	26.8608
2.186	204	4.4538	13.345	112	27.1908
3.172	200	6.4638	13.493	108	27.4908
4.095	196	8.3428	13.624	104	27.7588
4.954	192	10.0948	13.743	100	28.0038
5.755	188	11.7258	13.852	96	28.2238
6.497	184	13.2418	13.948	92	28.4218
7.190	180	14.6508	14.035	88	28.5988
7.833	176	15.9588	14.114	84	28.7588
8.427	172	17.1718	14.183	80	28.8988
8.978	168	18.2948	14.245	76	29.0249
9.489	164	19.3338	14.300	72	29.1374
9.959	160	20.2928	14.350	68	29.2372
10.393	156	21.1768	14.393	64	29.3256
10.792	152	21.9928	14.431	60	29.4038
11.162	148	22.7428	14.465	56	29.4726
11.499	144	23.4318	14.495	52	29.5335
11.811	140	24.0638	14.521	48	29.5867
12.093	136	24.6418	14.543	44	29.6334
12.352	132	25.1718	14.563	40	29.6742
12.591	128	25.6548	14.581	36	29.7097
12.807	124	26.0958	14.596	32	29.7407
13.004	120	26.4968			

As 32° F. is the freezing point we stop at that point, as there would be no economy in going to that point, even if it were a possibility. The point of greatest economy by marine engineers is now considered to be about 124° F., at which point the changes of temperature are not so radical as with more vacuum, and a greater degree of cold in its action on the surfaces of piston and cylinder.

We believe in a less vacuum as a means of greater economy; and that some of the examples of compounding, as shown in this work, are but an approach to the highest economy in the application of steam to motive power.

AN IMPROVED DRAUGHT GAUGE FOR CHIMNEYS.

[The following article is from *The Locomotive*. It contains so much that is valuable that it is put upon record in permanent form for the engineer, who can compute closely the questions most nearly connected with chimney draft, height, area, etc. :]

The influence of the chimney upon the working and economy of a steam-power plant is a factor of the greatest importance, and is one which, in too many cases, does not receive, in its design, location and execution, the consideration which should be given to it.

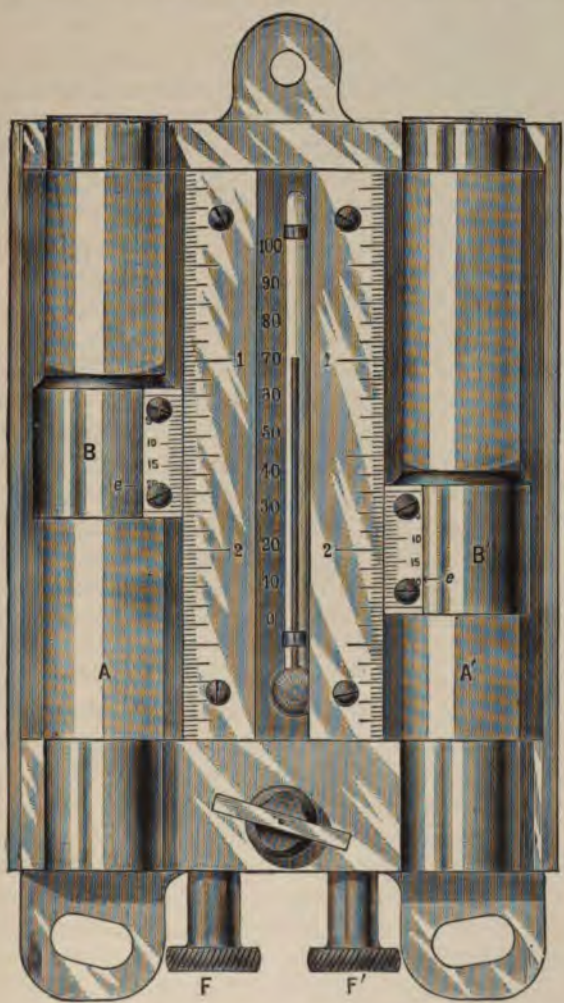
The function of a chimney is, primarily, to furnish sufficient draught to properly burn the fuel; secondly, to carry off the products of combustion. If the chimney is so constructed that the first of the above-named conditions is properly fulfilled, the second will, in general, follow as a natural consequence.

In designing a chimney for any given boiler plant, due regard should be paid to its location with regard to the surrounding buildings or adjacent hills, if there are any, the general direction of the prevailing winds, etc., as all these conditions have a direct and often a very great influence upon the proper working of the chimney. The chimney should be well constructed, the foundation should be firm enough to prevent any unequal settling which would be liable to crack the walls, the bricks should be carefully laid, care should be exercised that no air holes exist in the shaft of the chimney or the flue leading to it. The chimney, if of considerable size, should be built with double walls; the inner stack or core should be entirely independent of the outer one. This construction serves two important purposes: it prevents undue loss of heat by radiation, and prevents the excessive, unequal expansion and contraction of the outer stack, which might occur if it were a single shaft exposed on the inside to the heat of the escaping gases, and on the outside to the atmospheric temperature, the difference of which in some cases is as great as 600° F. This adds greatly to the very important element of the strength and durability of the outer shell of the chimney.

The cause of the draught power of a chimney may best be illustrated by assuming a particular case and following its working. Let us suppose we have a chimney 100 feet high from the top of the grate bars, the point from which the height of a chimney should always be reckoned. Suppose the temperature of the external air is 60° F., the temperature at the bottom of the chimney 400° F., which is about right in a well-arranged plant, and the barometer stands at 29.92 inches.

Then it is evident that we shall have in the chimney a column of the hot gases, the temperature of which is 400° F., and the height 100 feet.

The density or weight per cubic foot of these gases, when twenty-four pounds of air are supplied to each pound of coal burned, will be about .0482 pounds, while the density of the external air will be about .0764 pounds per cubic foot. Now it is plain that in this case the pressure of a column of the atmospheric air 100 feet high will be 7.64 pounds per square foot, while the



pressure of a similar column of the chimney gases would be but 4.82 pounds. Now as the pressure of that portion of the atmosphere above the chimney-top is evidently the same on the top of the column of hot gases as it is on the surrounding air at the same height, it may be neglected, and we need consider only the gases for the given height of chimney and the same height of the external air. Now in the case we are considering, the difference in the weights of the column of atmospheric air at 60° and the chimney gases at

400° is for a height of 100 feet 7.64–4.82=2.82 pounds per square foot, and it is this excess of pressure of the external air over that in the chimney which causes it to flow into the chimney through every opening into it. In properly-arranged boiler furnaces the only available opening is, of course, through the layer of incandescent fuel on the grate; in its passage through the fuel all the incoming air is heated and forced upward in its turn, and thus the process goes on continuously.

Now it is evident that if we can measure this unbalanced pressure in the chimney, we have a means of determining whether the chimney is "drawing" as well as its height should indicate, and if it is not, it may aid us in discovering where the fault lies, and so remedy it. This, the instrument shown on the preceding page, enables us to do with very great accuracy.

It has been designed and made by this company, who felt the need of something for their own use which would give more accurate and reliable results than the crude siphon gauges heretofore used. We are not aware that anything at all approaching it, in accuracy or completeness, has ever been made or used for this purpose.

The cut shows the instrument full size. A and A′ are glass tubes suitably mounted, as shown, and communicating with each other by means of a passage through the base, which passage may be closed by means of the stop cock shown. Surrounding the glass tubes are the two brass rings B and B′. These rings are attached to blocks which slide in dovetailed grooves in the body of the instrument, back of the 3-inch scales, and may be easily moved up and down by screws, the milled heads of which are shown at F, F′. The 3-inch scales are divided into fortieths of an inch, and read to thousandths of an inch by the verniers *e* and *e′*, which are attached to the sliding rings B, B′. This arrangement of scale and vernier is exactly the same as that of the ordinary Brown & Sharpe vernier caliper, with which every machinist is familiar, and is so adjusted that when the instrument is perpendicular, and the tops of the brass rings B and B′ are at exactly the same height, the reading of each is precisely the same. This being the case, it is evident that if the two short rings are set at different heights, as shown in the figure, the difference in their readings will give the difference of level between them. The thermometer shown in the center of the instrument is for the purpose of noting the temperature of the external air at the time of making observations, without the trouble of taking along an extra thermometer. The method of using the instrument is as follows:

At any convenient point, as near the base of the chimney as possible, a hole is made large enough to insert a thermometer to ascertain the temperature of the chimney. (This is something that it is extremely important to know, for other reasons than those connected with the use of the above instrument, and facilities for so doing should always be provided when a chimney is built.) The most available place is generally in the main flue leading from the boiler to chimney, and about twelve inches from the side of the chimney. The height from this opening to the top of chimney, and also to top of grates, should be noted for reference.

The chimney gauge is then attached to some convenient wall by means of small screws, the holes for which are shown in the cut. The tubes are then filled about half full of water, when the verniers afford an easy means of setting it exactly perpendicular. One end of a flexible rubber tube is then inserted into the upper end of one of the glass tubes (which are both open at the upper end) and the other end of the tube is inserted in the chimney flue. Then it is evident that the surface of the water in one of the tubes is open to the atmosphere, and that in the opposite tube is in communication with the somewhat lesser pressure of the hot gases in the chimney, and consequently the water in the tube communicating with the chimney will rise to an amount dependent upon the difference of pressure inside and outside of the chimney. The tubes B, B′ are then adjusted by means of the screws F, F′, until their upper ends are just tangent to the surface of the water in the two tubes. As the surface assumes a curved form in consequence of the capillary action of the sides of the tubes, this may be done with very great accuracy. The reading of the two scales is then taken, and their difference gives the height to which the water has risen. At the same time the temperature of the flue is noted, as well as that of the external atmosphere. Comparison may then be made with the following table, which has been computed by us for use in connection with investigations of chimney draught. The calculations have been made for a chimney 100 feet high, with various temperatures outside and inside of the flue, and on the supposition that the temperature of the chimney is uniform from top to bottom. This is the basis on which all calculations respecting the draught-power of chimneys have been made by Rankine and all other writers, so far as we know, but it is very far from the truth in most cases. The difference will be quickly shown by comparing the reading of the above described gauge with the table given. For other heights than 100 feet, the theoretical height is very easily found by simple proportion, thus: suppose the external temperature is 60°, the temperature of flue 386°, height of chimney 137 feet, then under 60° at the top of the table and opposite to 386° in the left hand margin, we find .52″.

Then 100 : 137 :: .52″ : .71″ which is the required height for a 137-foot chimney, and similarly for any other height.

Some interesting facts relative to the cooling of the gases in chimneys have been developed by us, of which we shall give an account in a month or two. For instance, in one chimney, 122 feet in height, we noted the following: Temperature at the base, 320°; temperature at the top, 230°, and the amount by which the height of water column in the gauge fell short of the theoretical, as given above for uniform temperature, was accounted for to less than the thousandth of an inch.

HEIGHT OF WATER COLUMN DUE TO UNBALANCED PRESSURE IN CHIMNEY ONE HUNDRED FEET HIGH.

Temperature in the Chimney.	*Temperature of the External Air—Barometer*, 14.7.										
	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°
200	.453″	.419	.384	.353	.321	.292	.263	.234	.209	.182	.157
210	.470	.436	.401	.371	.338	.309	.280	.251	.227	.200	.175
220	.488	.453	.419	.388	.355	.326	.298	.269	.244	.217	.192
230	.505	.470	.436	.405	.372	.344	.315	.286	.261	.234	.209
240	.520	.488	.451	.421	.388	.359	.330	.301	.276	.250	.225
250	.537	.503	.468	.438	.405	.376	.347	.319	.294	.267	.242
260	.555	.528	.484	.453	.420	.392	.363	.334	.309	.282	.257
270	.568	.534	.499	.468	.436	.407	.378	.349	.324	.298	.273
280	.584	.549	.515	.482	.451	.422	.394	.365	.340	.313	.288
290	.597	.563	.528	.497	.465	.436	.407	.379	.353	.326	.301
300	.611	.576	.541	.511	.478	.449	.420	.392	.367	.340	.315
310	.624	.589	.555	.524	.492	.463	.434	.405	.380	.353	.328
320	.637	.603	.568	.538	.505	.476	.447	.419	.394	.367	.342
330	.651	.616	.582	.551	.518	.489	.461	.432	.407	.380	.355
340	.662	.638	.593	.563	.530	.501	.472	.443	.419	.392	.367
350	.676	.641	.607	.576	.543	.514	.486	.457	.432	.405	.380
360	.687	.653	.618	.588	.555	.526	.497	.468	.444	.417	.392
370	.699	.664	.630	.599	.565	.538	.509	.480	.455	.428	.403
380	.710	.676	.641	.611	.578	.549	.520	.492	.467	.440	.415
390	.722	.687	.652	.622	.589	.561	.532	.503	.478	.451	.426
400	.732	.697	.662	.632	.598	.570	.541	.513	.488	.461	.436
410	.743	.708	.674	.643	.610	.583	.553	.524	.499	.472	.447
420	.753	.718	.684	.653	.620	.591	.563	.534	.509	.482	.457
430	.764	.730	.695	.664	.632	.602	.574	.545	.520	.493	.468
440	.774	.739	.705	.674	.641	.612	.584	.555	.530	.503	.478
450	.783	.749	.714	.684	.651	.622	.593	.564	.540	.513	.488
460	.793	.758	.724	.694	.660	.632	.603	.574	.549	.522	.497
470	.802	.768	.733	.703	.670	.641	.612	.584	.559	.532	.507
480	.810	.776	.741	.710	.678	.649	.620	.591	.566	.540	.515
490	.820	.785	.751	.720	.687	.659	.630	.601	.576	.549	.524
500	.829	.791	.760	.730	.697	.669	.639	.610	.586	.559	.534

HOW TO TEST FEED WATER FOR BOILERS.

Feed-water heaters are a matter of great importance; they are not always put in as they should be, nor are they given credit for all that they do, or even all that they are capable of, and in a great many cases they are not used, as they might be, for the profit or benefit of the owner. Testing the temperature of feed water for a boiler, is not an agreeable or desirable undertaking at all times, but it is a matter which can be done every hour in the day, if the engineer in charge will only think so. It is a matter not generally understood, that the feed water varies a great deal whether it is tested under pressure or in the open air. Water cannot and will not show any temperature greater than 212°, if, indeed, it does that, unless it is under pressure. It is remarkable that engineers will insist in drawing water out of a boiler under 60 or 80 pounds pressure, and dip a thermometer in the current of water which is running away from the boiler into the open air, and then wonder why the feed water does not show the same result! If the reader will refer to Fig. 1, in which A represents a side of the feed-water heater, B the feed pipe to the boiler from the upper portion of the heater, C, D, E, F, are all for the testing of feed water, and will be explained further on. Fig. 3 is a crude, but simple and reliable, method of testing any thermometer, and it is a very desirable proceeding to test thermometers, for we have found them varying 15° to 20° from the standard which we have, and always refer to in any test of pressure, or steam, or for temperature of feed water, whenever we are working around boilers or in any steam work. Take a tin can or pail, anything which will hold water three inches deep or over that, and put it upon a fire, or anywhere else, to boil; when it is boiling, then enter the thermometer bulb into the water an inch or more in depth, and notice whether it records 212° or 220°, or any other point, and also notice that the water is kept boiling until the observation is complete; whatever the variation is between 212° and the record of the test, remember that and make the allowance in all future observations taken with that thermometer. It is very seldom that we find a thermometer which shows less than 212° at boiling.

If we refer to Fig. 1 again, there is a cross put in the feed pipe from the heater to the boiler, from which the feed pipe proper leads off at B, the pipe which is continued down to C, branches off again at D, having an outlet, say one-quarter of an inch in diameter upon one side and one and one-half inches upon the other. We have found these arrangements sometimes put upon the heater of one maker by another who was desirous of making a test of his opponent's feed-water heater, and it is somewhat curious that the most of these tests are made by means of thermometers exposed to the open air,

while, as a matter of fact, the heater is used in its every-day work "under pressure;" the temperature of the water drawn from the boiler itself, will not be over 212°, if tested at the point D or E, no matter if the boiler was ten feet distant, and the pressure 80 pounds.

We will now refer to Fig. 2, in which A represents the glass tube of the thermometer correctly graduated, and used only after it has been thoroughly tested, D is a cast-iron plug which fits into the top of the cross, immediately over the boiler feed pipe B, Fig. 1; into the top of D is drilled the hole for a half-inch gas-pipe plug B, which has been cupped out, and under it a piece of rubber packing, C, fitted. The holes in B and D are slightly larger than the thermometer tube, and the rubber is punched so as to fit close; when

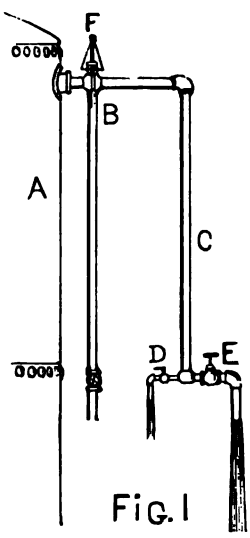


Fig. 1

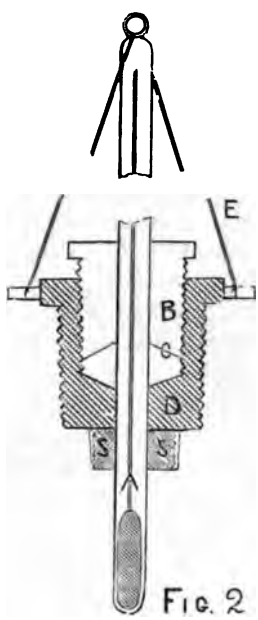


Fig. 2

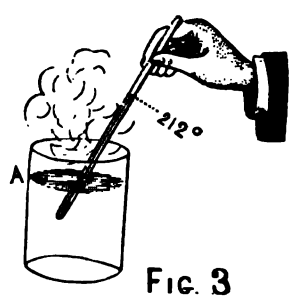


Fig. 3

the tube has been put into place, the rubber slipped down upon it, and the plug, B, screwed up, so that the bulb will be held below the crossing of the other pipe, we are ready to put the plug into the top of the cross and commence operations. As a safeguard the cord E is led from a small peg in each side of the plug through the ring in the top of the thermometer, so as to prevent its moving up by the pressure. In this disposition of the thermometer the boiling point should always be left above the top of the plug.

With this arrangement, which any engineer can readily fix up for himself, it is perfectly easy to test correctly and completely what the temperature of feed water is, which is passing into the boiler, and it can be done for fifty cents beyond the price of the thermometer, and these, from a reliable maker, will cost from $1.30 to $1.50 each. If there is an angle valve in the feed near the boilers, it is a first-rate place in which to put the thermometer so as

to know at what temperature the water enters the boilers, but whenever the apparatus is put in, let the bulb of the thermometer *always remain in the current of water which is under pressure.* Water boils at the level of the sea at 212°, and for each 500 feet above the level of the sea, it boils at one degree less than 212° ; never test steam or water under pressure unless you put the thermometer into the current of moving water or steam.

LUSTERLESS FINISH ON TEMPERING STEEL.

A fine lusterless surface on tempered steel can be procured by either of the following operations : After the steel article has been tempered, it should be rubbed on a smooth iron surface with some pulverized oil-stone until it is perfectly smooth and even, then laid upon a sheet of white paper and rubbed back and forth until it acquires a fine dead finish. Any screw holes or depressions in the steel must be cleaned beforehand with a piece of wood and oil-stone. This delicate, lusterless surface is quite sensitive, and should be rinsed with pure, soft water only, when the article will be found to have a fine, lusterless finish.

PATTERN VARNISH.

A varnish has been patented in Germany for foundry purposes and machinery, which it is claimed dries as soon as put on, gives the patterns a smooth surface, and is a good filler. This varnish is prepared in the following manner : Thirty pounds of shellac, ten pounds of Manilla copal and ten pounds of Zanzibar copal are placed in a vessel, which is heated externally by steam, and stirred from four to six hours, after which 150 parts of the finest potato spirit are added, and the whole heated during four hours to 87° C. This liquid is dyed by the addition of orange color, and can then be used for painting the patterns. When used for painting and glazing machinery, it consists of thirty-five pounds of shellac, five pounds of Manilla copal, ten pounds of Zanzibar copal and 150 pounds of spirit.

THE CALORIMETER TEST.

RULE FOR MAKING IT.

We give the following old but simple rule for a Calorimeter test: Take steam from main pipe near boiler with ½-inch pipe—the pipe must be thoroughly protected by covering with hair felt; the lower end of pipe should be closed, and ⅛-inch holes drilled so as to form a rose; the holes should be close to bottom of cap, so as not to trap water; the valve should be within easy reach; a can (bright tin is preferable) holding twelve to fifteen pounds of water should be provided, with sufficient opening in top to insert steam pipe and take temperature; this also should be well protected with hair felt; a small scale, steelyard, or spring balance, can be used for weighing; put exactly ten pounds water in the can, note its temperature, move the scale weight out one pound, so as to have just eleven pounds water when test is complete; blow steam through pipe to free it of any water of condensation, insert pipe in can, and when just one pound of steam has been condensed (eleven pounds water in can) shut off steam and note temperature of water. The difference is the caloric.

This formula is based, as all are, on the total heat of steam latent and sensible, less the temperature of water above zero, and can be calculated thus: Latent heat 966, sensible 212=1178, less the temperature of 10 pounds water, which leaves 1178—80=1098. Now we turn one pound steam into 10 pounds water, and find the temperature has risen from 80° to 176°, a gain of 96°. This we multiply by 11 pounds water, 11×96=1056, nearly equal to our 1098 total available heat; 100° rise of temperature, if no heat had been absorbed by the can containing the water, would be dry steam. It has been found by experiment that 96° under the above rule is dry steam. Had the rise of temperature been but 80°, the amount of water in the steam would have been 20 per cent. The tables approximate closely to the actual amount of water carried over in the steam:

RISE OF TEMPERATURE OBSERVED ABOVE THE 96° SUPERHEATED STEAM.	PERCENTAGE OF WATER IN STEAM.
96 degrees dry steam.	5 per cent. water.
92 " "	10 " "
88 " "	20 " "
80 " "	30 " "
71 " "	40 " "
63 " "	50 " "
54 " "	60 " "
46 " "	70 " "
37 " "	80 " "
28.5 " "	90 " "
20 " "	95 " "
15 " "	100 all water.
11.5 " "	

IRON PAINT.

Iron paint, as it is termed—a paint composed of pulverized iron and linseed oil varnish—is a recent German invention, and is intended for covering damp walls, outer walls, and, in short, any place or vessel exposed to the action of the open air and to the weather. Should the article to be painted be exposed to frequent changes of temperature, linseed oil varnish and amber varnish are mixed with the paint intended for the first two coats, without the addition of any artificial drying medium. The first coat is applied rather thin, the second a little thicker and the last in a rather fluid state. The paint is equally adapted as weather-proof coating for wood, stone and iron; nor is it necessary to previously free the latter from rust, grease, etc., a superficial cleaning being sufficient.

JOULE'S EQUIVALENT.

The conversion of heat into work is the main purpose of the steam engine. In other words, we could not use coal in the steam cylinder, and water is therefore made the medium to convey the products of combustion, transferred from coal to water, through the steam boiler, and the steam in the fluid state, under various pressures, passes through all the pipes, valves, ports, is controlled by the valves so that it is more or less economically used according to their action, and the only way we have of establishing this action for economical comparisons for the purpose of ascertaining the power, is by means of the indicator. We must, therefore, have some standard, and for that purpose frequent reference is made to the unit or equivalent. Mr. Joule, at Cambridge, England, in 1845 or '46 first exhibited the apparatus, and at that time he considered that it required 781.5 pounds to equal the raising of one pound of water 1° Fahrenheit, while in another case it was slightly increased, but was subsequently settled that the precise equivalent of the unit of heat was 772 pounds raised one foot high, and this is what is termed Joule's equivalent.

Joule's equivalent has been generally substantiated by scientific research and is accepted as true. It may be defined as the work done raising one pound through one foot, and is called either the foot-pound, or the unit of heat; or the heat required to raise the temperature of a pound of water 1° Fahrenheit, and is the equivalent of 772 units of work. When a pound of water at the temperature of boiling, 212° Fahrenheit, or 100° Centigrade, when at the atmospheric pressure, passes into a state of steam of the same temperature, 966.6 units of heat, equivalent to 746,215 units of work, disappear, being converted into internal and external work.

Mr. Joule also has announced what absolute cold was, and this is considered proven by scientific research at 461.2° below zero of the Fahrenheit scale or — 274° on the Centigrade scale. The theory upon which Joule's equivalent is rested is that heat is motion, and that absolute rest would be absolute cold, and that the atoms of which bodies consist, are always in motion, and if they were brought to absolute rest, this would give the result which he first announced, and which has generally been accepted by the best authorities, as 461.2° below zero, Fahrenheit.

COLORING SOFT SOLDER YELLOW.

When brass is soldered with soft solder, the difference in color is so marked as to direct attention to the spot mended. The following method of coloring soft solder is given by the Metallarbeiter: First prepare a saturated solution of sulphate of copper (bluestone) in water, and apply some of this on the end of a stick to the solder. On touching it with a steel or iron wire it becomes coppered, and by repeating the experiment the deposit of copper may be made thicker and darker. To give the solder a yellower color, mix one part of a saturated solution of sulphate of zinc with two of sulphate of copper, apply this to the coppered spot, and rub it with a zinc rod. The color can be still further improved by applying gilt powder and polishing.

On gold jewelry or colored gold, the solder is first coppered as above, then a thin coat of gum or isinglass solution is applied and bronze powder dusted over it, which can be polished after the gum is dry and made very smooth and brilliant; or the article may be electro-plated with gold, and then it will all have the same color.

On silverware the coppered spots of solder are rubbed with silvering powder, or polished with the brush and then carefully scratched with the scratch brush, then finally polished.

RECIPES FOR SOLDERING FLUID.

One dram each of powdered copperas, borax and prussiate of potash; one-half ounce powdered sal ammoniac; 3½ ounces fluid muriatic acid; let the mixture cut all the zinc it will and then dilute with one pint of water. This is something extra for soldering raw edges of tin or galvanized iron. The above quantity of fluid costs fifteen cents.

Add granulated zinc or zinc scraps to two fluid ounces of muriatic acid until hydrogen ceases to be given off; add one teaspoonful of ammonium chloride; shake well and add two fluid ounces of water.

Also a good fluid for soldering bright tin can be made of well-pounded resin and sweet oil. It was used years ago by the tinners of Great Britain for soldering planished ware made in those days, and is excellent for soldering fine work, silver and plated ware; it can be wiped off with a clean rag and leave no stain or scratches.

SAFETY-VALVE PROBLEMS.

1. Do you wish to know the pressure of the ball as it hangs? Ball weighs 90 pounds. Multiply the weight of the ball by the distance in inches the weight hangs from the center of the fulcrum, say 30; divide that by the distance in inches from the center of the valve to the center of the fulcrum, say 5; add the weight of the valve and lever in pounds, say 20; divide this by the square inches in the valve, say 20; and the result will be the pressure in pounds on a square inch of the ball, equal to 28.

$$90\times30\div5+20\div20=28$$

2. If you wish a certain pressure with a ball you have never used, then say the valve is 4 inches in diameter, the area is 12.566. Multiply this by the pressure you want in pounds, say 40; subtract from it the weight of valve and lever, say 16; multiply this by the distance from the center of the valve to the center of the fulcrum, say 4; divide this by the weight of the ball in pounds, say 80; and the distance in inches the ball must be from the center of the fulcrum will be the result, as 24⅛.

$$12.566\times40—16\times4\div80=24\tfrac{1}{8}.$$

3. If you wish a ball upon the lever for a certain pressure in pounds, multiply the area of the valve 7.068 by the pressure required 50 pounds, take out the weight of the valve and lever; multiply that result by the distance from the center of the valve to the center of the fulcrum, say 3 inches; divide this result by the distance from where you put the ball, 21 inches, to the center of the fulcrum, and this will give you the weight of the ball.

$$7.068 \times 50 \times 3 \div 21 = 50\tfrac{1}{2} \text{ pounds, weight of ball.}$$

RULE FOR ASCERTAINING SIZE OF SAFETY-VALVE FOR ANY GIVEN GRATE SURFACE.

The required aggregate area of safety-valve to be placed upon boilers, may be expressed by the formula,

$$A = \frac{22.5 \times G}{P\ 8.62}$$

in which A is area of safety-valve in inches; G is area of grate in square feet; P is pressure of steam in pounds per square inch, to be carried on the boiler above the atmosphere. The following table gives the results of the formula for one square foot of grate as applied to boilers used at different pressures:

PRESSURES PER SQUARE INCH.

10.	20.	30.	40.	50.	60.	70.	80.	90.	100.	110.	120.
1.21	0.79	0.58	0.46	0.38	0.33	0.29	0.25	0.23	0.21	0.19	0.17

(area corresponding to one square foot of grate.)

Example.—Required, area of safety-valve in square inches for boiler running at 80 lbs. pressure and 30 feet grate surface.

For 1 square foot from table at 80 lbs.—0.25
Square feet grate surface — .30

Area of valve in square-inches =7.50

If a forced or artificial draft is used, the estimate is based on a consumption of 16 lbs. of fuel for each square foot of grate surface.

This rule was furnished by the scientific commission which framed the inspection law for the city of Philadelphia.

Tarnished colored gold articles, it is said, may be restored by the following method: Dissolve one ounce of bicarbonate of soda, half an ounce of chloride of lime, and half an ounce of common salt, in about four ounces of boiling water. Take a clean brush, and wash the article with the hot solution for a few seconds, and rinse immediately in two clean waters. Dry in warm sawdust, and finally rub over with tissue paper.

WATER IN THE CYLINDER.

It has now become generally accepted among the best authorities that the indicator diagram will show the water or presence of water in the cylinder when working. It must first be positively settled that there are no leaks about the valves or piston or that there is nothing which shall disturb the true diagram, for unless the engine is in mechanical perfection as nearly as possible, the real reading of a diagram does not give us the facts, and ambiguous quantities enter in. We must, therefore, be sure that the engine is mechanically in first-class condition and proper order; then having arrived at the point of the stroke where steam is cut off, with precision, we can figure for water in the steam. This varies considerably with the conditions under which the valves are working. If a great deal of water is present, it makes a radical difference in the expansion curve. We can readily plot upon an indicator diagram the pressure of steam with regard to its density and volume, by reference to the table of Properties of Saturated Steam, if we wish to do so; but in doing this, we have certain other factors which must be taken into account, which involve many figures, and also points about which the best authorities differ so widely that we have not carried it out in this volume; that rather belongs to the science of the indicator than to its practice, and is a point upon which the best authorities do not by any means agree.

To cut Gauge Glasses to length take a drill rod, sharpen the end and turn it at right angles to rod, like cut, and harden the end without drawing the temper. Be careful in hardening not to get the point too hot, as its being so small it is liable to be burned.

Every engineer will find this a handy tool.

When a glass is to be cut find the length, and with this tool cut a ring around the *inside* of the glass and it will usually break off square at that point at once. If it does not, a little heat applied at that point will hasten, or if laid down a few minutes it will crack off.

A glass cut on the outside, unless cut very deep with a file or stone, is liable to crack anywhere.

BABBITT METAL.

Nearly half a century ago Isaac Babbitt of Taunton, Mass., originated the alloy which has since been known as Babbitt Metal. It is highly valued for its anti-friction qualities as compared with other metals. Isaac Babbitt was a goldsmith by trade and made the first Britannia ware produced in this country. He was honored with a gold medal for his discovery of his anti-friction alloy, and was also presented with $20,000 by the Congress of the United States. Below are several formulas for preparing Babbitt metal for different uses:

WHITE ALLOY, OR BABBITT METAL.

A—Copper	10
Tin	72
Antimony	18
	100

This alloy is recommended for high-speed machinery journal boxes.

B—Copper	1
Tin	48
Antimony	5
Lead	2
	56

This alloy is more economical than the above and has a more greasy touch than the first-named above, but is not so desirable for high speed.

C—Lead	32
Zinc	20
Antimony	48
	100

This alloy will resist a rapid friction. The zinc should be melted first, then add the other metals.

D—Lead	90
Antimony	100

This alloy is suitable for pillow blocks, agricultural or other slow working machinery.

[From Hamilton's Useful Information for Railroad Men.]

USEFUL NUMBERS FOR RAPID APPROXIMATION.

Feet	×	.00019	=miles.
Yards	×	.0006	=miles.
Links	×	.22	=yards.
Links	×	.66	=feet.
Feet	×	1.5	=links.
Square inches	×	.007	=square feet.
Circular "	×	.00546	= " "
Square feet	×	.111	= " yards.
Acres	×4840.		= " "
Square yards	×	.0002066	=acres.
Width in chains	×	8.	= " per mile.
Cubic feet	×	.04	=cubic yards.
Cubic inches	×	.00058	= " feet.
U. S. bushels	×	.046	= " yards.
" "	×	1.244	= " feet.
" "	×2150.42		= " inches.
Cubic feet	×	.8036	=U. S. bushels.
" inches	×	.000466	= " "
U. S. gallons	×	.13368	=cubic feet.
" "	×	231.	= " inches.
Cubic feet	×	7.48	=U. S. gallons.
Cylindrical feet	×	5.878	= " "
Cubic inches	×	.004329	= " "
Cylindrical inches	×	.0034	= " "
Pounds	×	.009	=cwt. (112 lbs.)
Pounds	×	.00045	=tons (2240 lbs.)
Cubic feet water	×	62.5	=lbs. avoirdupois.
" inches "	×	.03617	= " "
Cylindrical foot of water	×	49.1	= " "
Cylindrical inches of water	×	.02842	= " "
U. S. gallons of water	+	13.44	=cwt. (112 lbs.)
U. S. gallons of water	+	268.8	=tons.
Cubic feet water	+	1.8	=cwt. (112 lbs.)
" " "	+	35.88	=tons.
Cylindrical foot of water	×	5.875	=U. S. gallons.
Column of water, 12″ high; 1 inch diameter			=34 pounds.
183,346 circular inches			=1 square foot.
2,200 cylindrical inches			=1 cubic "
French metres	×	3.281	=feet.
Kilogrammes	×	2.205	=avoirdupois lbs.
Grammes	×	.0022	= " "

To write upon terra-cotta tablets, dip the clay tablet in milk, with a few drops of acid added, and then dry. When this is done you can write upon it as easily as upon paper.

THE PROPERTIES OF SATURATED STEAM.

In the tables which follow, steam is considered from M. Regnault's results, and "total heat" is from the Fahrenheit zero.

The bases of all his results are, that the saturated steam maintains relatively density, temperature, and pressure unchangeably to each other, and it naturally follows that if one of these properties are for any cause changed, that the others also change in some fixed ratio, or that each of the others pass through relative changes in proportion, so that all the factors change proportionately, and the basis remains the same or unchanged.

In specific heat, water exceeds any other substance known, and the specific heat of any body is the amount of heat required to raise its temperature 1°, taking the amount of heat required to raise the temperature of water 1° (an equal weight) as the unit. The specific heat of superheated steam, as stated by M. Regnault, is .48, while saturated steam is .305; and the same authority states, that as saturated steam is always at its dew point, and, if its density is maintained, all the loss of heat encountered must be supplied by its partial condensation, and, while it does not contain water necessarily, its temperature cannot be any higher than that of the water from which it was generated. It has, until recently, been supposed that the specific heat of saturated steam was nothing, as it did not require an additional amount of heat to raise its temperature, and it was also supposed that the latent heat gave the increase of temperature; but M. Regnault has determined differently, and that an addition is required of .304° to its total heat to raise the temperature one degree.—See Tables I, II, III, IV and V.

TABLE I.

PROPERTIES OF SATURATED STEAM, AT PRESSURES FROM ONE POUND TO TWO HUNDRED POUNDS ON THE SQUARE INCH.

Elastic Force.		Heat, in Degrees Fahrenheit.					Volume, that of an equal weight of water at its greatest density being 1.	Weight of One Cubic Foot, in Decimals of a Pound.	Specific Gravity, the Atmosphere at 32° being 1.
		Sensible Heat.		Latent Heat.	Total Heat.				
In Pounds on the Square Inch.	In Inches of Mercury at 32°.		Difference.			Difference.			
1	2.0375	102.		1043.05	1145.05		20690	.0029	.087
5	10.1875	162.37	9.26	1001.9	1163.46	2.82	4627	.0135	.167
10	20.375	193.29	4.93	979.60	1172.89	1.50	2429	.0257	.318
15	30.5625	213.07	3.47	965.85	1178.92	1.05	1669	.0373	.463
20	40.75	228.	2.8	955.5	1183.5	.8	1280	.0467	.604
25	50.9375	240.2	2.3	947.	1187.2	.7	1042	.0598	.742
30	61.125	250.4	2.	939.9	1190.3	.6	881	.0707	.877
35	71.3125	259.3	1.7	933.7	1193.	.5	764	.0815	1.012
40	81.5	267.3	1.5	928.1	1195.4	.4	676	.0921	1.142
45	91.6875	274.4	1.4	923.2	1197.6	.4	608	.1035	1.272
50	101.875	281.	1.3	918.6	1199.6	.4	552	.1139	1.402
55	112.0625	287.1	1.2	914.4	1201.5	.4	506	.1232	1.529
60	122.25	292.7	1.1	910.5	1203.2	.3	467	.1355	1.654
65	132.4375	298.	1.1	906.8	1204.8	.3	434	.1436	1.779
70	142.625	302.9	1.	903.4	1206.3	.3	406	.1536	1.904
75	152.8125	307.5	.9	900.3	1207.8	.3	381	.1636	2.029
80	163.	312.	.9	897.1	1209.1	.2	359	.1736	2.151
85	173.1875	316.1	.8	894.3	1210.4	.3	340	.1833	2.271
90	183.375	320.2	.8	891.4	1211.6	.2	323	.1930	2.391
95	193.5625	324.1	.8	888.7	1212.8	.3	307	.2030	2.511
100	203.75	327.8	.7	886.1	1213.9	.2	293	.2127	2.631
105	213.9375	331.3	.7	883.7	1215.0	.2	281	.2224	2.751
110	224.125	334.6	.6	881.4	1216.0	.2	269	.2319	2.871
115	234.3125	338.	.6	879.	1217.0	.2	259	.2410	2.990
120	244.5	341.1	.6	876.9	1218.0	.2	249	.2508	3.105
125	254.6875	344.2	.6	874.7	1218.9	.2	239	.2598	3.227
130	264.875	347.2	.6	872.6	1219.8	.2	231	.2698	3.347
135	275.0625	350.	.5	870.7	1220.7	.1	223	.2788	3.467
140	285.25	352.9	.6	868.6	1221.5	.1	216	.2888	3.589
145	295.4375	355.6	.6	866.8	1222.4	.2	209	.2978	3.697
150	305.625	358.3	.5	864.9	1223.2	.2	203	.3078	3.819
155	315.8125	360.9	.5	863.1	1224.	.2	196	.3168	3.927
160	326.	363.4	.5	861.4	1224.8	.2	191	.3263	4.042
165	336.1875	365.9	.5	859 7	1225.6	.2	186	.3353	4.157
170	346.375	368.2	.4	856.1	1226.3	.2	181	.3443	4.270
175	356.5625	370.6	.5	856 4	1227.	.1	176	.3538	4.383
180	366.75	372.9	.4	854.8	1227.7	.1	172	.3628	4.495
185	376.9375	375.3	.5	853.1	1228.4	.1	168	.3713	4.607
190	387.125	377.5	.4	851.6	1229.1	.1	164	.3800	4.720
195	396.3125	379.7	.4	850.1	1229.8	.2	160	.3888	4.832
200	407.5	381.7	.3	848.6	1230.3	.1	157	.3973	4.945

TABLE II.

AREA OF CIRCLES FROM ¼" DIAMETER UPWARDS.

Inches. Diameter	Area.	Inches. Diameter	Area.	Inches. Diameter	Area.	Inches. Diameter	Area.	Inches Diameter	Area.	Inches. Diameter	Area.	Inches. Diameter	Area.	Inches. Diameter	Area.
0.25	.04908	11.5	103.16	22.75	406.49	34.	907.92	45.25	1606.1	56.5	2507.1	67.75	3605.0	79.	4901.6
0.5	.1963	11.75	108.43	23.	415.47	34.25	921.32	45.5	1625.9	56.75	2529.4	68.	3 31.6	79.25	4932.7
0.75	.4417	12.	113.09	23.25	424.55	34.5	934.82	45.75	1645.8	57.	2551.7	68.25	3658.4	79.5	4963.9
1.	.7854	12.25	117.85	23.5	433.73	34.75	948.41	46.	1661.9	57.25	2574.1	68.5	3685.2	79.75	4995.1
1.25	1.227	12.5	122.71	23.75	443.01	35.	962.11	46.25	1680.0	57.5	2596.7	68.75	3712.2	80.	5026.5
1.5	1.767	12.75	127.67	24.	452.39	35.25	975.90	46.5	1698.2	57.75	2619.3	69.	3739.2	80.25	5058.0
1.75	2.405	13.	132.73	24.25	461 86	35.5	989.80	46.75	1716.5	58.	2642.0	69.25	3766.4	80.5	5089.5
2.	3.141	13.25	137.88	24.5	471.43	35.75	1003.7	47.	1734.9	58.25	2664.9	69.5	3793.6	80.75	5121.2
2.25	3.976	13.5	143.13	24.75	481.10	36.	1017.8	47.25	1753.4	58.5	2687.8	69.75	3821.0	81.	5153.0
2.5	4.908	13.75	148.48	25.	490.87	36.25	1032.0	47.5	1772 0	58.75	2710.8	70	3848.4	81.25	5184.8
2.75	5.939	14.	153.93	25.25	500.74	36.5	1046.3	47 75	1790.7	59.	2733.9	70.25	3875.9	81.5	5216.8
3.	7.068	14.25	159.48	25.5	510.70	36.75	1060.7	48.	1809.5	59.25	2757.1	70.5	3903.6	81.75	5248.8
3.25	8.295	14.5	165.13	25.75	520.76	37.	1075.2	48.25	1828.4	59.5	2780.5	70.75	3931.3	82.	5281.0
3.5	9.621	14.75	170.87	26.	530.93	37.25	1089.7	48.5	1847.4	59.75	2803.9	71.	3959.2	82.25	5313.2
3.75	11.044	15.	176.71	26.25	541.18	37.5	1104.4	48.75	1866.5	60.	2827.4	71.25	3987.1	82.5	5345.6
4.	12.566	15.25	182.65	26.5	551.54	37.75	1119.2	49.	1885.7	60.25	2851.0	71.5	4015.1	82.75	5378.0
4.25	14.186	15.5	188.69	26.75	562.00	38.	1134.1	49.25	1905.0	60.5	2874.7	71.75	4043.2	83.	5410.6
4.5	15.904	15.75	194.82	27.	572.55	38.25	1149.0	49.5	1924.4	60.75	2898.5	72.	4071.5	83.25	5443.2
4.75	17.720	16.	201.06	27.25	583.20	38.5	1164.1	49.75	1943.9	61.	2922.4	72.25	4099.8	83.5	5476.0
5.	19.635	16.25	207.39	27.5	593.95	38.75	1179.3	50.	1963.5	61.25	2946.4	72.5	4128.2	83.75	5508.8
5.25	21.647	16.5	213.82	27.75	604.80	39.	1194.5	50 25	1983.1	61.5	2970.5	72.75	4156.7	84.	5541.7
5.5	23.758	16.75	220.35	28.	615.75	39.25	1209.9	50.5	2002 9	61.75	2994.7	73.	4185.3	84.25	5574.8
5 75	25.967	17.	226.98	28.25	626.79	39.5	1225.4	50.75	2022.8	62.	3019.0	73.25	4214.1	84.5	5607.9
6.	28.274	17.25	233.70	28.5	637.94	39.75	1240.9	51.	2042.8	62.25	3043.4	73.5	4242.9	84.75	5641.1
6.25	30.679	17.5	240.52	28.75	649.18	40.	1256.6	51.25	2062.9	62.5	3067.9	73.75	4271.8	85.	5674.5
6 5	33.183	17.75	247.45	29.	660.52	40.25	1272.3	51.5	2083.0	62 75	3092.5	74.	4300.8	85.25	5707.9
6.75	35.784	18.	254.46	29.25	671.95	40.5	1288.2	51.75	2103.3	63.	3117.2	74.25	4329.9	85.5	5741.4
7.	38.484	18.25	261.58	29.5	683.49	40.75	1304.2	52.	2123.7	63.25	3142.0	74.5	4359.1	85.75	5775.0
7.25	41.282	18.5	268.80	29.75	695.12	41.	1320.2	52.25	2144.1	63.5	3166.9	74 75	4388.4	86.	5808.8
7.5	44 178	18.75	276.11	30.	706.86	41.25	1336.4	52 5	2164.7	63.75	3191.9	75.	4417.8	86.25	5842.6
7.75	47.173	19.	283.52	30.25	718.69	41.5	1352.6	52.75	2 85.4	64.	3216.9	75.25	4447.3	86.5	5876.5
8.	50.265	19.25	291.03	30.5	730.61	41.75	1360.0	53.	2206.1	64.25	3242.1	75.5	4476 9	86.75	5910.5
8.25	53.456	19.5	298.64	30.75	742.64	42.	1385.4	53.25	2227 0	64.5	3267.4	75.75	4506.6	87.	5944.6
8.5	56.745	19.75	306.35	31.	754.76	42 25	1401.9	53.5	2248.0	64.75	3292.8	76.	4536.4	87.25	5978.9
8.75	60.132	20.	314.16	31.25	766.99	42.5	1418.6	53.75	2269.0	65.	3318.3	76 25	4566.3	87.5	6013.2
9.	63.617	20.25	322.06	31.5	779.31	42.75	1435.3	54.	2290.2	65.25	3343.8	76.5	4596.3	87.75	6047.6
9.25	67.200	20.5	330.06	31.75	791.73	43.	1452.2	54.25	2311.4	65.5	3369.5	76.75	4626.4	88.	6082 1
9.5	70.882	20.75	338.16	32.	804.24	43.25	1469.1	54.5	2332.8	65.75	3395.3	77	4656.6	88.25	6116.7
9.75	74.662	21.	346.36	32.25	816.86	43.5	1486.1	51.75	2354.2	66.	3121.2	77.25	4686.9	88.5	6151.4
10.	78.540	21.25	354.65	32.5	829.57	43.75	1508.3	55.	2375.8	66.25	3447.1	77.5	4717.3	88.75	6186.2
10.25	82.516	21.5	363.05	32.75	842.39	44.	1520.5	55.25	2397.4	66.5	3473.2	77.75	4747.7	89.	6221.1
10.5	86 590	21.75	371.54	33.	855.30	44.25	1537.8	55.5	2419.2	66.75	3499.3	78.	4778.3	89.25	6256.1
10.75	90.762	22.	380.13	33.25	868.30	44.5	1555.2	55.75	2441.0	67.	3525.6	78.25	4809.0	89.5	6291.2
11.	95.033	22.25	388.82	33.5	881.41	44.75	1572.8	56.	2463.0	67.25	3552.0	78.5	4839.8	89.75	6326.4
11.25	99.402	22.5	397.60	33.75	894 61	45.	1590.4	56.25	2485.0	67.5	3578.4	78.75	4870.7	90.	6361.7

TABLE III.

HYPERBOLIC LOGARITHMS.

No.	Log.	No.	Log.	No.	Log.	No.	Log.	No.	Log.	No.	Log.
1.05	.049	2.4	.875	3.75	1.322	5.15	1.639	6.5	1.872	7.85	2.061
1.1	.095	2.45	.896	3.8	1.335	5.2	1.649	6.55	1.879	7.9	2 067
1.15	.14	2.5	.916	3.85	1.348	5.25	1.658	6.6	1.887	7.95	2.073
1.2	.182	2.55	.936	3.9	1.361	5.3	1.668	6.65	1.895	8.	2.079
1.25	.223	2.6	.956	3.95	1.374	5.33	1.673	6.66	1 896	8.05	2.086
1.3	.262	2.65	.975	4.	1.386	5.35	1.677	6.7	1.902	8.1	2.092
1.33	.285	2.66	.978	4.05	1.399	5 4	1.686	6 75	1.91	8.15	2.098
1.35	.3	2.7	.993	4.1	1.411	5.45	1.696	6.8	1.917	8.2	2.104
1.4	.336	2.75	1.012	4.15	1.423	5.5	1.705	6.85	1.924	8.25	2.11
1.45	.372	2.8	1.08	4.2	1.435	5.55	1.714	6.9	1.931	8.3	2.116
1.5	.405	2.85	1.047	4.25	1.447	5.6	1.723	6.95	1.939	8.35	2.119
1.55	.438	2.9	1.065	4.3	1.459	5.65	1.732	7.	1.946	8.35	2.122
1.6	.47	2.95	1.082	4.35	1.465	5.66	1.733	7.05	1.953	8.4	2.128
1.65	.5	3.	1.099	4.35	1.47	5.7	1.74	7.1	1.96	8.45	2.134
1.66	.506	3.05	1.115	4.4	1.482	5.75	1.749	7.15	1.967	8.5	2.14
1.7	.531	3.1	1.131	4.45	1.493	5.8	1.758	7.2	1.974	8.55	2.146
1.75	.56	3.15	1.147	4.5	1.504	5.85	1.766	7.25	1.981	8.6	2.152
1.8	.588	3.2	1.163	4.55	1.515	5.9	1.775	7.3	1.988	8.65	2.158
1.85	.612	3.25	1.179	4.6	1.526	5.95	1.783	7.33	1.991	8.66	2.159
1.9	.642	3.3	1.194	4.65	1.537	6.	1.792	7.35	1.995	8.7	2.163
1.95	.668	3.33	1.203	4.66	1.54	6.05	1.8	7.4	2.001	8.75	2.169
2.	.693	3.35	1.209	4.7	1.548	6.1	1.808	7.45	2.008	8 8	2.175
2.5	.718	3.4	1.224	4.75	1.558	6.15	1.816	7.5	2.015	8.85	2.18
2.1	.742	3.45	1.238	4.8	1.569	6.2	1.824	7.55	2.022	8.9	2.186
2.15	.765	3.5	1.253	4.85	1.579	6.25	1.833	7.6	2.028	8.95	2.192
2.2	.788	3.55	1.267	4.9	1.589	6.3	1.841	7.65	2.035		
2.25	.811	3.6	1.281	4.95	1.599	6.33	1.845	7.66	2.036		
2.3	.833	3.65	1.295	5.	1.609	6.35	1.848	7.7	2.041		
2.33	.845	3.66	1.297	5.05	1.619	6.4	1.856	7.75	2.048		
2.35	.854	3.7	1.308	5.1	1.629	6.45	1.864	7.8	2.054		

TABLE IV.

EFFECT OF EXPANSION WITH EQUAL VOLUMES OF STEAM.

The theoretical economy of using steam expansion is as follows. A like volume of steam being expended in each case, and expanded to fill the increased spaces.

Point of Cutting Off.	Expansion Number.	Mean Pressure of Steam.	Gain Per Cent. in Power.	Point of Cutting Off.	Expansion Number.	Mean Pressure of Steam.	Gain Per Cent. in Power.
.1	10.	3.302	230.	.5	2.	1.693	69.3
.125	8.	3.079	208.	.6	1.66	1.507	50.7
.166	6.	2.791	179.	.625	1.6	1.47	47.
.2	5.	2.609	161.	.666	1.5	1.405	40.5
.25	4.	2.386	139.	.7	1.42	1.351	35.1
.3	3.33	2.203	120.	.75	1.33	1.285	22.3
.333	3.	2.099	110.	.8	1.25	1.223	20.5
.375	2.66	1.978	97.8	.875	1.143	1.131	13.1
.4	2.5	1.916	91.6	.9	1.11	1.104	10.4

In this illustration no deductions are made for a reduction of the temperature of the steam while expanding or for loss by back pressure.

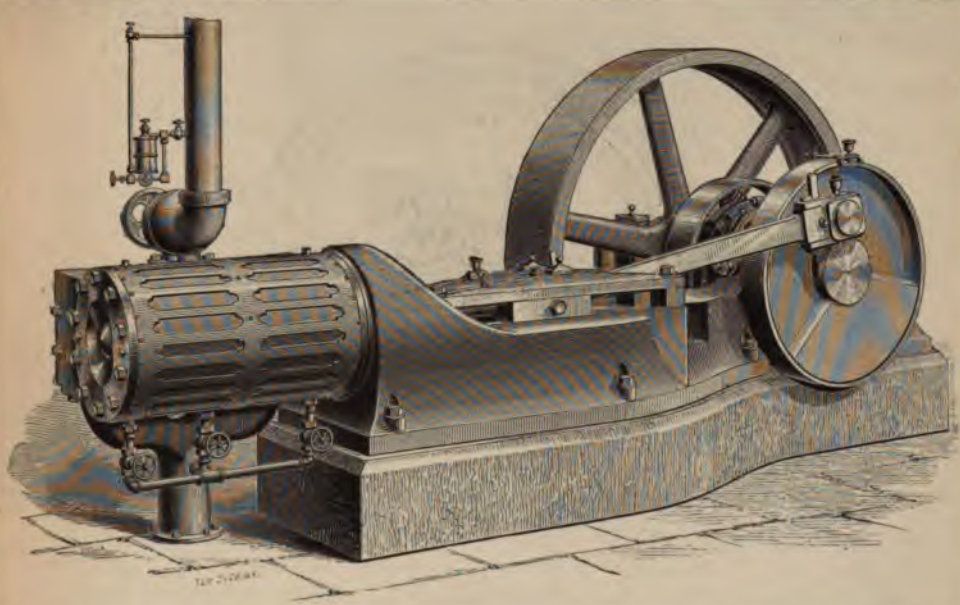
The same relative advantage follows in expansion as above given, whatever may be the initial pressure of the steam.

TABLE V.

FRACTIONS OF INCH EXPRESSED IN DECIMALS.

	Decimals.
1–64	= .015625
2–64= 1–32	= .03125
3–64	= .046875
4–64= 2–32= 1–16	= .0625
6–64= 3–32	= .09375
8–64= 4–32= 2–16=1–8	= .125
10–64= 5–32	= .15625
12–64= 6–32= 3–16	= .1875
14–64= 7–32	= .21875
16–64= 8–32= 4–16=2–8=1–4	= .25
18–64= 9–32	= .28125
20–64=10–32= 5–16	= .3125
22–64=11–32	= .34375
24–64=12–32= 6–16=3–8	= .375
26–64=13–32	= .40625
28–64=14–32= 7–16	= .4375
30–64=15–32	= .46875
32–64=16–32= 8–16=4–8=2–4=1–2=	.5
34–64=17–32	= .53125
36–64=18–32= 9–16	= .5625
38–64=19–32	= .59375
40–64=20–32=10–16=5–8	= .625
42–64=21–32	= .65625
44–64=22–32=11–16	= .6875
46–64=23–32	= .71875
48–64=24–32=12–16=6–8=3–4	= .75
50–64=25–32	= .78125
52–64=26–32=13–16	= .8125
54–64=27–32	= .84375
56–64=28–32=14–16=7–8	= .875
58–64=29–32	= .90625
60–64=30–32=15–16	= .9375
62–64=31–32	= .96875
64–64=32–32=16–16=8–8=4–4=2–2=1	.00000

THE ARMINGTON & SIMS ENGINE.



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PROVIDENCE, R. I.

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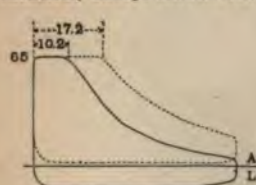
THE DEANE PATENT

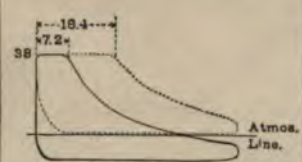
INDEPENDENT CONDENSER

Is simple and effective, easily attached, can be set in any convenient position. Its use is not attended with danger to the engine, as is the case with other machines for producing the same results.

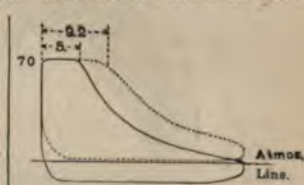
To illustrate the saving of steam effected by the use of the Deane Condenser, the following indicator diagrams have been selected. In each case the two lines were traced within A FRACTION OF A MINUTE OF EACH OTHER, THE LOAD, STEAM PRESSURE, SPEED AND ALL OTHER CIRCUMSTANCES being identical, except that in one case the condenser was attached, and in the other it was disconnected.



Taken from the Cylinder of a "Harris-Corliss" Engine, 20 in. by 48 in. The mean effective pressure is 36.7 lbs. per square in. by either diagram. Without the condenser the steam was cut off at 17.2 in., with the condenser at 10.2 in. The steam required to operate the condenser would increase this last to 16.6 in. The Net Saving, is therefore, 6.6 in. of steam for every single stroke of the engine, or 38 per cent. of that used without condensation.



Taken from the cylinder of a "Brown" Engine, 16 in. by 42 in. The mean effective pressure is 23.2 lbs. per square inch by either diagram. Without the condenser the steam was cut off at 18.4 in., with the condenser at 7.2 in. The steam required to operate the condenser would increase this last to 8 in. The Net Saving is, therefore, 10.3 in. of steam for every single stroke of the engine, or 56 per cent. of that used without condensation.



Taken from one cylinder of a pair of Hartford "Buckeye" Engines, having 20 in. by 30 in. cylinders. The mean effective, pressure is 36.7 lbs. per square inch by either diagram. Without the condenser the steam was cut off at 9.2 in., with the condenser at 5 in. Adding steam required to operate the condenser this last would be increased to 5.5 in. The Net Saving is, therefore, 3.7 in. of steam per single stroke of the engine, or 40.2 per cent. of that used without condensation.

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NEW YORK,	BOSTON,	PHILADELPHIA,	CHICAGO,
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50 to 1000 H. P.

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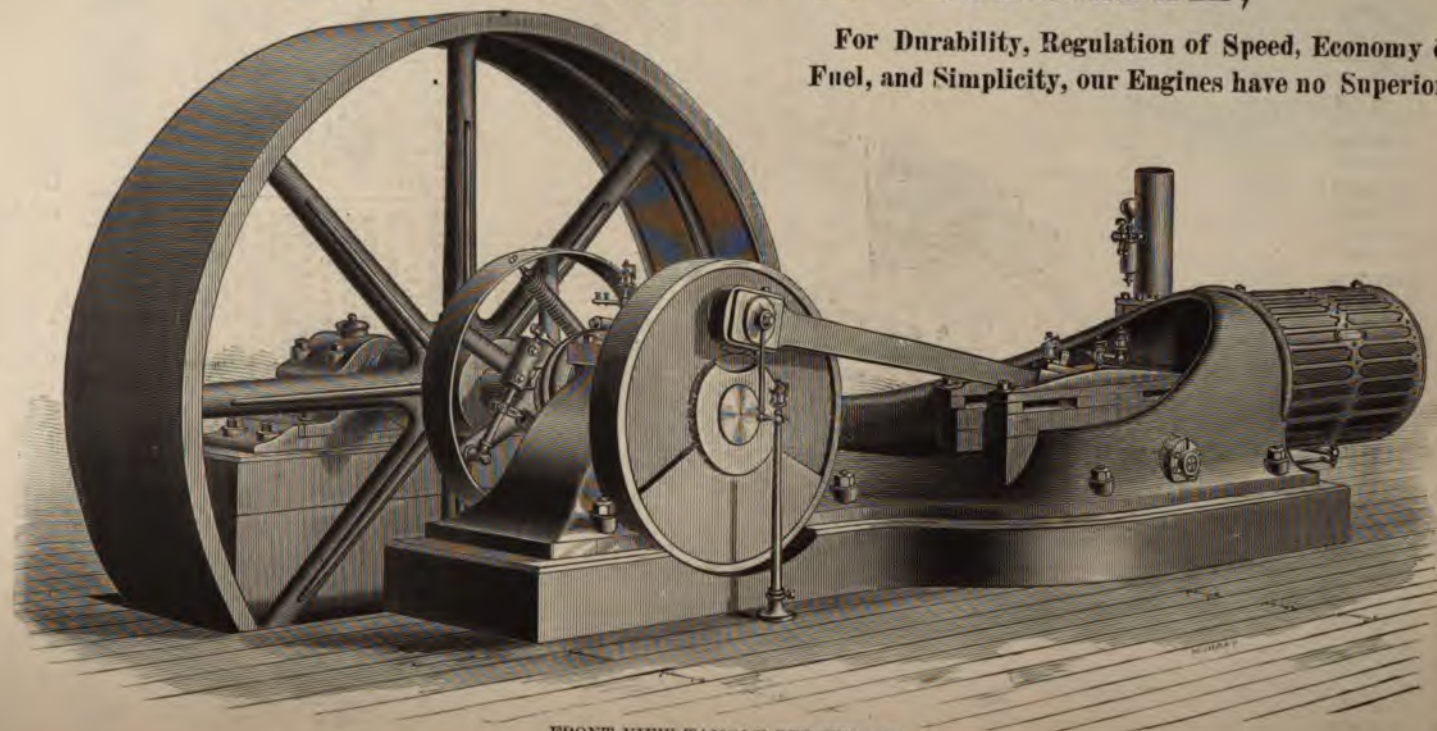
GIRDER BED ENGINES,
50 to 750 H. P.

THE BUCKEYE ENGINE,

For Durability, Regulation of Speed, Economy of Fuel, and Simplicity, our Engines have no Superior.



FRONT VIEW TANGYE BED ENGINE.

BUCKEYE ENGINE CO., Salem, Ohio.

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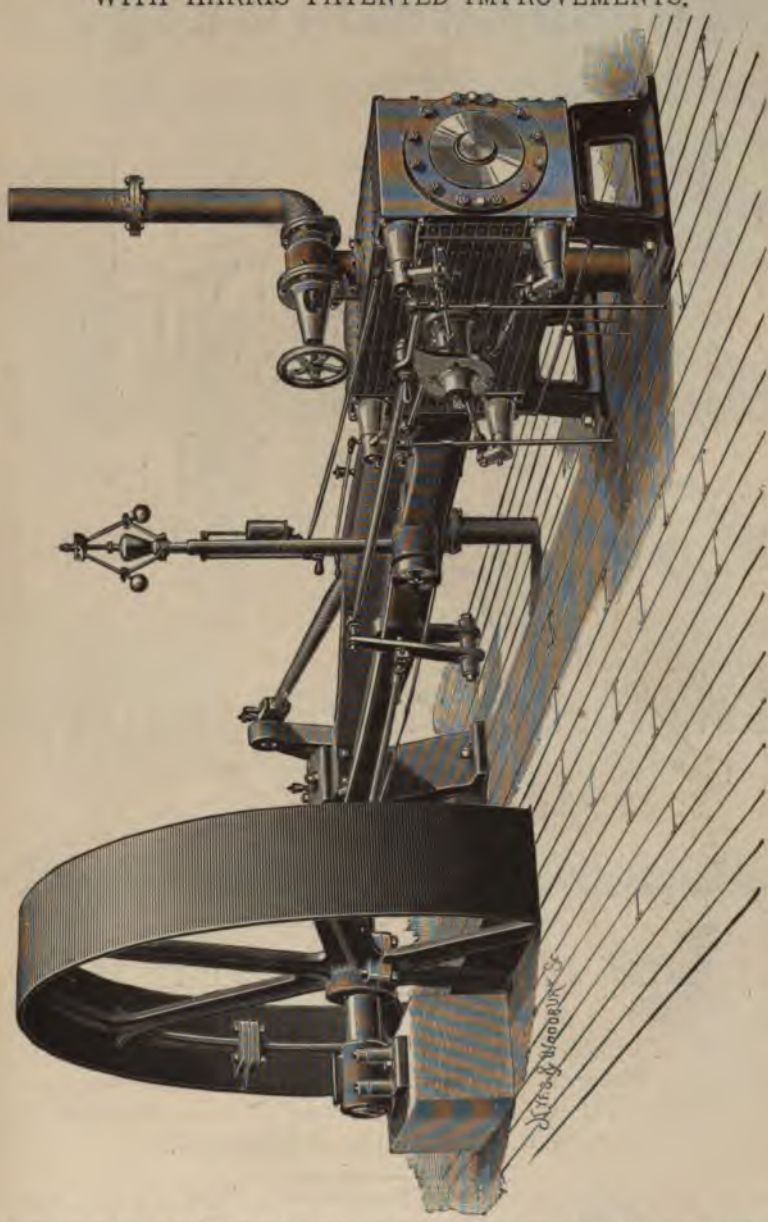

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BUILDERS OF

Pumping Machinery.

SINGLE
—AND—
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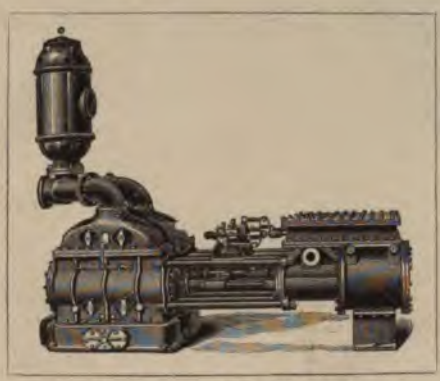

Duplex Compound Pumping Engine.

STEAM
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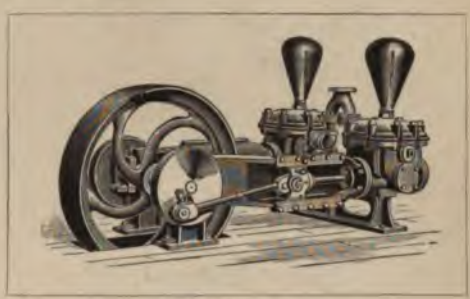
Geared Power Pump.



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